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1984-85 REVIEW
ARCTIC MARINE TRANSPORTATION RESEARCH AND DEVELOPMENT PROGRAM

TRANSPORT CANADA

EXECUTIVE SUMMARY

Background

This report has been prepared in fulfillment of a Treasury Board requirement that the Arctic Marine Transportation Research and Development Program be subjected to a comprehensive review prior to any submission to Cabinet for approval for the continuation of these special efforts past March 31, 1986. The focal points of this review have been the documention of the acheivements of the current program and the assessment of future alternatives. Some aspects of program activities and program management were also examined.

Information Sources

Several sources of information were used to prepare this review. As a first step, thirty-one firms across the country, selected to represent a cross-section of the types of firms involved in Canada's marine industry, were visited to identify and confirm industrial benefits of the program and continuing needs for government supported marine industry research. As a second step, relevant information was collected from program documents and by discussions with government personnel. As a final step this information and the program were examined by an independent Industry Review Panel. The members of the panel were selected to give the perspectives of the different elements of the marine industry and the different regions of Canada. None of the Panel members had been directly involved in the program.

Scope of the Review

This review covers six aspects of the program: the structure of program activities; the implications of project results for the Regulations under the Arctic Waters Pollution Prevention Act; the improvements in government marine services that have resulted from the program; industrial benefits from the program; future alternatives; and the management of the program.

Review of Program Structure

For the review of program structure the tables showing projects by identified needs for information, systems and projects to achieve the strategic program objective (i.e. by tactical objectives) were brought up to date and a set of tables showing projected expenditures by these needs were added. The Industry Review Panel concluded that, by and large, these identified areas of study were appropriate and that program expenditures were (just) adequate for the work undertaken. The Panel also commented that greater concentration of efforts might be

appropriate in the future. No work has been initiated or planned as yet for five of the areas of identified needs. For two of these, work would appear to be premature at present and, for another, work under the program is not necessary because of the large number of studies already being carried out by the private sector. The remaining two areas involve problems related to the management of the program.

Regulatory Implications

The assessment of regulatory implications of project results was carried out by an independent expert. Fifty projects were examined of which thirty-six had results important for regulatory purposes. Some of these results were conclusive enough that revisions of the Regulations are, or could be, in process now. Other results, while important need further confirmation and analysis before making changes in the Regulations. The review of these reports also provided an opportunity to assess the technical quality of the research. With very minor exceptions, the technical quality of the work was judged to be excellent.

Impacts on Government Services

At the start of the program, the government was faced with many special problems in providing infrastructure services for (eventual) regular, year-round navigation in Arctic waters. These problems have been addressed and some have already been solved under the program. Necessary improvements have been made in methods of providing navigational aids and communications, of identifying and mapping ice hazards, of providing hydrographic services and meteorological forecasts, of tracking and controlling oil spills, and of ice transiting and icebreaking. Some of these improvements also have application to areas outside the Arctic.

Industrial Benefits

In addition, while the program was not designed as an industrial assistance program, it has provided three types of industrial benefits. It has allowed the Canadian marine transportation industry to develop a specialized area of expertise. It has assisted in the development in Canada of a number of different types of technologies. It has helped some firms develop specific, marketable products and services.

Future Alternatives

Four alternatives for the future of the program were examined: letting the program lapse after March 31, 1986; continuing a program exclusively focused on Arctic problems; continuing with a program expanded to consider similar problems in other Canadian ice-infested waters (i.e. where Arctic-type conditions are encountered outside the Arctic); and

continuing Arctic research as but one part of a general marine transportation R&D program. Needs for, and potential benefits of, research on Arctic problems, ice-infested waters problems and general marine problems were identified. However the types of research needed on general marine problems are distinctly different from the Arctic type problems and would not fit readily, or meaningfully, with the Arctic research. Research on problems in other ice-infested waters is, however, closely related to and sometimes indistinguishable from the Arctic research. Given the imminent development of offshore oil on the East Coast and the importance to the Canadian economy of the other Canadian waterways where ice is a problem, it is recommended that Phase III of the program starting in April, 1986 address both Arctic marine transportation problems and similar problems of operating under Arctic-type conditions in other Canadian waters.

Program Management

The examination of the management of the program centred around a few problem areas. The central co-ordination unit lacks the up-to-date information necessary to fulfill its role. A simple, milestone-based information system is needed, together with commitment from the project managers to keep this up-to-date. Industry has complained that it is not being kept informed of plans, activities and results. Dedicated resources are needed for a technical liaison and information function to ensure transfer of technology to Canadian firms. The Industry Review Panel supported, and emphasized the importance of, international, intra-government and government/private-sector co-operation and co-ordination for this research and development work. They recommended an expanded role for the Marine Advisory Board to facilitate government/ private-sector co-operation and co-ordination.

Future Objectives

The fact that solving Arctic problems, while still important, does not appear to be as urgent as it was four years ago, together with the recommendation to broaden the scope of the program to include other ice-related problems, imply a change in the strategic focus of the program. A modified statement of the strategic objective for the program has been proposed which incorporates the broader scope of study, stresses the importance of improving seasonal marine transportation in the Arctic as a means to the long-term goal of year-round navigation, and, while recognizing the primary focus of the program on government responsibilities for regulations and services, highlights the intention of assisting the technological development of Canadian industry through addressing these technologically challenging problems.

1989 Evaluation

Finally, the Industry Review Panel recommended that the modified program be approved for five years (1986-87 to 1990-91) but be subjected to an independent comprehensive evaluation in 1989. A combination of approaches in the 1983 Evaluation and in the 1984-85 Review is suggested to effect this evaluation of the modified program.

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C. Listing of Projects by Tactical Objectives

D. Projected Expenditures 1981-86 by Tactical Objectives

1. INTRODUCTION

1.1 Background

On June 25, 1981 Cabinet approval was given for a program of research and development work on Arctic marine transportation problems. The program involved work to be carried out by Fisheries and Oceans and Environment Canada as well as Transport Canada. Although the proposed program was designed as a five year program, Treasury Board initally approved funding for the first three years only: 1981-82, 1982-83, and 1983-84. Funding for the final two years was contingent upon a prior satisfactory evaluation of the program. This evaluation was carried out by the Bureau of Management Consulting (BMC) in 1983. Treasury Board subsequently approved funding for 1984-85 and 1985-86.

Funding for the program thus now terminates at the end of March 1986. Cabinet approval is required before these efforts can continue beyond that date. A further review of the program was also called for before any extension of the work would be approved. BMC was engaged by program management to carry out this 1984-85 Review of the Arctic Marine Transportation Research and Development Program.

1.2 Purposes of 1984-85 Review

The evaluation of the program in 1983 concentrated on whether the program was appropriately structured to achieve its stated objectives, although attention was paid to the question of industrial and technological spin-offs of the work done under the program and to questions of program management. Several areas of study were identified which were determined to be necessary for the achievement of objectives but which had been overlooked in setting up the program. A number of worthwhile industrial spin-offs from project work were also identified. Some observations were made on ways in which the management of the program might be improved. A follow-on project identified the resource contributions made by industry towards program projects and the expected impacts of this work on future research work plans of the companies.

While one purpose of the 1984-85 Review has been to update the review of program structure carried out in 1983, the major objectives have been somewhat different.

One of the primary purposes of the 1984-85 Review has been to document as completely as possible the achievements to date of the program. Since one of the explicit purposes of the

research efforts is to provide reliable information to confirm the appropriatness of, or indicate necessary changes to, the Regulations under the Arctic Waters Pollution Prevention Act, one of the objectives of this Review has been to identify the implications of research results to date for these regulations. Another explicit purpose of the program is to provide information, systems and products necessary for the government to be able to provide essential services to marine transportation in the Arctic. The parallel objective of this Review has been to identify achievements to date of the program in this regard. Another less direct, but equally important, purpose of the program is to assist in the development of Canadian marine transportation technology and expertise. Thus another objective of the Review has been to examine the impacts of the program on Canadian technology and industry.

While such material will speak to the question of how worthwhile these government efforts have been, a fundamental concern is what should happen after March 1986 when funding approval for these efforts expires. Thus another primary purpose of this Review has been to consider implications of various courses of action after that time, including options to simply terminate the program or to carry it on as it has been directed or with some modifications. This information is intended to help inform those that have to make decisions on the future of these efforts.

It should be noted that the information required to address these questions is narrative and descriptive rather than statistical. The type and scope of the program and its objectives do not lend themselves to quantitative analysis.

To summarize, the purposes of this 1984-85 Review of the program have been to follow-up on certain aspects of the 1983 Evaluation, to document program achievements relating to regulations, government marine services and industrial spin-offs, and to consider some alternative future courses of action.

1.3 Sources of Information

A variety of different sources of information were used to accomplish these tasks.

Project reports, program status reports from Environment Canada, Fisheries and Oceans, and Transport Canada; and the Arctic Marine Transportation R&D Project Databank were used to update the tables on projects by specific tactical objectives of the program (see Appendix C). These sources

were also used to prepare tables of program expenditures by tactical objectives (Appendix D).

Identifying regulatory impacts of the work to date presented a problem. Most of the information is too new to have resulted in actual or even proposed changes to regulations, as such changes take considerable time to formulate. It was therefore decided to commission a sub-report on the implications of results to date for the Regulations under the Arctic Waters Pollution Prevention Act. Mr. S. Mathews, who had been acting as a technical expert for the Review, was engaged to do this work. Mr. Mathews is the former head of the Institute of Marine Dynamics of the National Research Council and was part of the team that prepared these Regulations in the first place. In order to carry out this work, Mr. Mathews reviewed and analysed fifty reports carried on for Transport Canada under the program (the work carried out for Fisheries and Oceans and for Environment Canada is aimed at improving government services in the Arctic rather than at regulatory change).

The information on impacts on goverment services was collected to some extent from reports received but primarily from discussions with key personnel in the government departments responsible for providing the services.

Information on technological and industrial spin-offs of the program was collected for the 1983 Evaluation from project managers. For this Review all reported technological impacts and specific industrial spin-offs (i.e. marketable products and services) were tested and confirmed in the visits to marine industry firms across the country.

The interviews with industry personnel were also used to collect information and opinions on the need for government supported marine industry research in Canada. The sample of firms visited (see Table 1.1) was selected to include the variety of types of firms in the industry, to include firms from all five of the regions in Canada, and to include both firms that had carried out research and development work with support from the program and firms that had not participated in the program.

TABLE 1.1

Canadian Marine Industry Firms Visited to Confirm Industrial Benefits of the Program and Discuss Needs for Research and Development Work.

Toronto and South-Western Ontario:	*Meteorological and Environmental Planning Ltd., *Optech Inc., Port Weller Dry Docks, *PhD. Associates.
Ottawa:	*Mechron Energy Ltd., *Davis Engineering, *German and Milne Inc., *Versatile Vickers Systems Inc., Norris Warming Canada Limited, *Arctec Canada Limited, *Canarctic.
Vancouver:	*International Submarine Engineering Ltd., Burrard Yarrow Corporation, Robert Allan Ltd.
Calgary and Edmonton:	*Melville Shipping., *Canadian Marine Drilling Limited (Dome), Esso Resources Canada Limited, *Monenco Consultants Limited (Martec), Petro-Canada Resources, Gulf Canada Resources Inc., Pallaster Resource Management, Northern Transportation Company Limited.
Montreal and Eastern Quebec:	Canadian Stone Marine Limited, Atlas Maritime Electronics, *MPB Technologies, Canadian Marconi Company, *Sanivan Inc.
St. John's:	C-CORE, *Acres Consulting Services Limited, Nordco Limited, Mobile Oil Canada Ltd.

* Firms that have carried out projects under the program.

In addition to these inputs from industry, the Canadian Shipbuilding and Ship Repairing Association circulated to its members the list of questions used to initiate discussions with the firms visited and asked for their comments. Seven quite different types of firms responded (see Table 1.2) and their responses have been used for this Review. One other firm that had been interviewed also sent in a written response. These responses are set out in Appendix A of this report.

TABLE 1.2

Member Firms of the Canadian Shipbuilding and Ship Repairing Association that Provided Written Input to the Review (see Appendix A for copies of these responses).

Arctec Canada Limited, Kanata, Ontario

Peter S. Hatfield Ltd., Vancouver, B.C.

John T. Hepburn, Limited, Toronto, Ontario

Pratt and Whitney Canada Inc., Industrial and Marine Division, Longueuil, Quebec

Rolls-Royce Industrial and Marine Limited, Montreal Quebec

Stelco Inc., Hamilton, Ontario

Port Weller Dry Docks, St. Catherines, Ontario

The government departments that have been involved in the program were also invited to state what they believed to be the needs for future research and development work. Some key personnel were interviewed and additional information was gained from reviewing Program Plans of some of the responsibility centres.

The final step in this Review was to submit the information collected to an independent panel of external experts from the Canadian marine industry for discussion and comments. This panel was selected by the Bureau of Management Consulting (BMC) to include only those whose firms had not directly benefited from the Arctic Marine Transportation Research and Development Program and to include a cross section of the industry. The panel members were:

Chairman: Mr. J. Leitch, Chairman of ULS International Inc., Toronto. (This firm both operates ships and builds them through its division, Port Weller Dry Docks. This latter firm built the MV Arctic.)

Other Members: Mr. P. Preville, Vice-President, Northern Transportation Company Limited, Edmonton. (This Crown Corporation operates a fleet of shallow draft vessels and barges to supply communities in the western Arctic.)

Prof. D. Muggeridge, Chairman, Ocean Engineering Research Group, Memorial University, St. John's (Memorial University is the only university in Canada that offers complete training in Naval Architecture. It also has a graduate program in ocean and marine engineering.)

Dr. A.E. Pallister, President, Pallister Resource Management Ltd., Calgary. (This firm collects, summarizes and distributes information and reports from the various Canadian off-shore petroleum operator's associations on behalf of the federal government and assists the firms to co-ordinate consortium research.)

Admiral R.W. Timbrell, President, Dominion Marine Association, Ottawa.

Mr. H.M. Walsh, President, Canadian Shipbuilding and Ship Repairing Association, Ottawa.

A seventh representative selected for the panel, Mr. James F. Hepburn, of John T. Hepburn Limited, Toronto (designers and builders of marine deck machinery) was unable to attend at the last moment.

Dr. J. Atack (of BMC) and Mr. S. Mathews presented material to the panel to initiate their discussions. Mr. W.F. Barnicke of BMC and Mrs. Pat Gibson of the Energy and R&D section of the Marine Transportation Administration of Transport Canada were also present at the panel meetings to assist the panel in their deliberations.

It should be noted that the original purpose of this panel was to provide input to this report. However, the Marine Administrator requested that their report be submitted

independently directly to the Marine Administration. While this was agreed to, in keeping with the original intent the observations and recommendations of the panel have been used extensively in this report. For the most part their observations and recommendations have been used without comment since the panel was part of the reviewing team. However in some cases the evaluators could not concur and reasons have been given for this disagreement.

As noted in the previous section, this type of information lends itself to narrative reporting rather than statistical analysis. The results of the program are very different types of events rather than meaningfully countable units. While opinions were sought on the value to Canada and Canadian industry of program efforts, this was from a cross-section of informed external observers, not from a random sample of the relevant publics. The attempt here has been made here simply to present objective, confirmed descriptions of activities and results and balanced reports of opinions, so that the reader may have an accurate picture from which to draw his or her own conclusions about the value of efforts to date and the value of continuing such efforts.

1.4 Organization of this Report

The information collected for this report and observations upon it have been divided into relevant subject areas.

Chapter 2 presents information and observations on the structure of the program.

Chapters 3, 4 and 5 consider the results to date of the program. Chapter 3 looks at the implications of completed work for the Regulations under the Arctic Waters Pollution Prevention Act. Chapter 4 reports on the impacts to date on methods of providing government services to marine transportation. Chapter 5 examines the benefits to Canadian industry in terms of technological development and specific commercial products and services.

Chapter 6 examines future alternatives for the program and proposes specific modifications for continued efforts. This review includes areas identified for future research and the conclusions of the Industry Review Panel concerning the scope of future efforts.

Chapter 7 addresses specific aspects of management of the program and proposes improvements.

Prevention Act. Chapter 4 reports on the impacts to date on methods of providing government services to marine transportation. Chapter 5 examines the benefits to Canadian industry in terms of technological development and specific commercial products and services.

Chapter 6 examines future alternatives for the program and proposes specific modifications for continued efforts. This review includes areas identified for future research and the conclusions of the Industry Review Panel concerning the scope of future efforts.

Chapter 7 addresses specific aspects of management of the program and proposes improvements.

2. PROGRAM STRUCTURE

The 1983 Evaluation of the program was primarily focused on the structure of the program. The major issue was whether or not it was reasonable to conclude that the program could achieve its objectives with the work that had been planned and/or undertaken. In this chapter we will first set out an overview of the structure of the program, through noting its objectives and activities, and then discuss comments made by the Industry Review Panel.

2.1 Program Objectives

The program has a hierarchy of objectives. The fundamental purpose, or strategic long-term objective, is:

> "to undertake mission-oriented research and development work in order to provide for the safe and efficient shipment of Arctic resources on a year-round basis by the late 1980's or the early 1990's through development of appropriate regulations, and the establishment, in conjunction with industry, of more efficient and effective services."

While this is the primary long-term objective, the program is also intended to have several other types of benefits over the long-term. These supplementary objectives are:

"1) To foster the development of transportation services to remote Arctic communities and resources.

2) To foster the development of safe, efficient, year-round marine transportation in Canada's Arctic waterways in ways that are compatible with protection of the environment and contribute effectively to national energy conservation goals.

3) To enable the provision of services and the exercise of regulatory responsibility to demonstrate Canadian sovereignty over Arctic waters and contribute to government objectives respecting sovereignty in the Arctic.

4) To ensure that every reasonable opportunity is granted to firms resident in Canada to have primary access to, and take advantage of, technological spin-offs of this research and development work in order to support the development of the Canadian industrial and service sectors."

The expected contributions of the program towards the achievement of these objectives are: (1) through research, to provide a knowledge base to resolve inherent technological problems of Arctic marine transportation and 2) through development work, to provide the systems and proven products necessary for the government to provide essential marine services to commercial transportation in the Arctic. These needs for knowledge, systems and proven products were set out as tactical objectives at the inception of the program. As one part of the 1983 exercise these initial tactical objectives were formalized as more precise statements of needs. A committee of external and internal Arctic marine experts was then convened to review the sufficiency of these tactical objectives and the projects planned and/or initiated for achieving the strategic objective of the program. This committee identified some requirements that had been overlooked in the initial plans. The identified areas of need are set out in Table 2.1 with the new requirements marked with asterisks. The full statement of tactical objectives is shown as Appendix B to this report.

2.2 Program Activities

In order to accomplish these objectives, the program managers have initiated a number of short-term projects and longer-term areas of study under specific areas of responsibility. For the 1983 Evaluation, all projects and areas of study were classified by tactical objective and reported in a set of tables showing the project number, the responsibility center, the projected status at March 31, 1984, the title and a brief description of the intent of the project or area of work. An updated version of these tables, showing current status and new projects, has been completed and is set out in Appendix C. It should be noted that some projects are directly relevant to more than one tactical objective. Where this is the case, they have been shown under all directly relevant tactical objectives.

As shown in these tables no projects have been initiated or planned to meet the needs specified in five of the tactical objectives:

2.2 Emergency and Rescue Procedures
3.2 Social, Economic and Ecological Impacts
3.3 Stationary Vessels
3.4 Operating Routes
4.8 General Design and Operating Information

These omissions will be discussed in the next section of this chapter.

TABLE 2.1

Identified Areas of Need for Knowledge, Systems and Products to Accomplish the Strategic Program Objective (* indicates new areas identified in 1983 Evaluation).

1. Regulatory: Design	1.1	Hull Design Criteria
	1.2	External Structural Materials and Assembly
	1.3	Ice Class Propellers and Housing
	1.4	Ice Class Rudders and Steering Gear
	1.5	Ship Propulsion Systems
	1.6	Protection of Exposed Machinery and Equipment
	1.7	Crew Accomodations
	1.8	Design of Artic Class Fishing Vessels
	1.9	Wharf Construction and Equipment
	1.10	Off-shore Drilling Units
2. Regulatory: Operations	2.1	Operating Procedures
	2.2	Emergency and Rescue Procedures
	2.3	Safety and Emergency Equipment
	2.4	Staffing and Training
	2.5	Survey, Repair and Salvage
	2.6	Operation of Arctic Class Fishing Vessels
3. Regulatory: General	3.1	Classification of Arctic Vessels and Areas
	*3.2	Social, Economic and Ecological Impacts
	*3.3	Stationary Storage Vessels
	*3.4	Operating Routes
	*3.5	Regulatory Overview
4. Operation of Vessels	4.1	Ship-based Ice Hazard Detection
	4.2	Communication Systems and Technologies
	4.3	Ship Monitoring and Warning Systems
	4.4	Arctic Navigational Methods and Systems
	4.5	Ship Ballasting
	4.6	Arctic Refuelling
	4.7	Crew Training
	*4.8	General Design and Operating Information
5. Government Services	5.1	Arctic Charting Equipment
	5.2	Remote Ice Measurement
	5.3	Arctic Climatology
	5.4	Local Ice Movement
	5.5	Ice/Weather Forecasting
	5.6	Ice Management
	5.7	Ice Transiting and Icebreaking Techniques
	5.8	Arctic Class Nav-Aids
	5.9	Ship Movement Planning and Monitoring
	5.10	Oil Spill Detection, Containment and Clean-up

A further set of tables was prepared for the 1984-85 Review showing actual and projected expenditure by tactical objectives over the five years for which the program has been approved. The detailed tables are set out in Appendix D to this report. Where individual projects fit under more than one tactical objective, the costs have been divided equally among the relevant objective areas.

Table 2.2 gives a summary of these expenditures for the full five year period by the five broad categories of tactical objectives plus "International Technology Exchange" and "Project Management and Program Review" (i.e., special aspects of program management).

As shown in this table, the bulk of the funds ($23 million out of almost $26 million) will have been spent in the three regulatory categories plus Government Services. This is to be expected as the primary thrust of this program has been towards ensuring that the government could fulfill its responsibilities for regulations and services rather than to assist directly in solving problems of commercial operators. In this respect, even the $2.3 million spent on "Operation of Vessels" is directed more at areas of government responsibility. Nonetheless most of the work indirectly benefits industry by providing information on how to design and operate ships for safer and more efficient navigation of Arctic waters.

2.3 Industry Review Panel Comments

The Industry Review Panel for the 1984-85 Review considered this material and concluded that the level of effort was adequate (just) for the work undertaken, although it suggested that it might be advisable to concentrate efforts on somewhat fewer areas of study in the future. Since the necessary work has been completed in some areas, some degree of concentration will occur as a matter of course, although this could be offset as events evolve by the need to look at new problems. Further, excessive concentration of efforts would mean that some essential areas for study would be neglected.

As to the areas of study themselves, the panel concluded that overall these had been well and appropriately chosen. They did suggest some specific additions for the future (which we will consider in Chapter 6) and did have a few areas of concern.

At least one panel member felt that the expenditures on 2.4 Staffing and Training ($180,000 over the five years) were premature and, possibly, inappropriate. The thought that the

TABLE 2.2

Projected Expenditures 1981/82 to 1985/86 by Category of Tactical Objective, Plus Expenditures on International Technology Exchange and Project Management/Program Review.

		Projected Expenditures 1981-86 ($K)
1.	Regulatory: Design	$ 9,394
2.	Regulatory: Operations	1,588
3.	Regulatory: General	1,057
4.	Operation of Vessels	2,341
5.	Government Services	11,017
6.	International Technology Exchange	148
7.	Project Management/Program Review	166
	Total	$25,711

work was premature was based on the fact that it will be a relatively long time before there will be regular year-round commercial shipping in the Arctic (especially given the fact that the time horizon for full-scale production of petroleum from the Arctic has been extended considerably since the program started). Thus, any conclusions based upon the knowledge and experience gained to date could be obsolete by the time they might be applied. The thought that the expenditures might be inappropriate was based on the belief that research in this area was more the responsibility of the private sector. However, these research efforts were primarily designed to keep the government aware of any special problems of operating in the Arctic that might require specific regulations. Further, the government does have to train its own Coast Guard staff for Arctic operations.

No other areas where program projects have been initiated or planned were identified as premature or inappropriate. However, the panel did comment that any work on 2.2 Emergency and Rescue Procedures would be premature because the full range of equipment necessary to do this is not yet available, and that any work on 3.2 Social, Economic and Ecological Impacts would be inappropriate given the extensive work that is now being done by members of the Arctic Petroleum Operators Association (APOA). As previously noted, no work has been done, or is planned, in these areas of study.

The panel did express a general concern that there should be sufficient co-ordination with the private sector to prevent duplication of effort, ensure transfer of technological information and ensure that the government did not undertake work that should be done by the private sector.

The government, of course shares these concerns and has taken intiatives in this respect. One example of government-industry co-ordination within the program has been the joint efforts of Environment Canada and the Canadian Offshore Oil Spill Research Association (COOSRA) which is financed by the member oil companies. Regular meetings are held between government personnel and COOSRA representatives. Joint sea trials have been held to test government and private sector results. An NRC PILP (Program for Industry/Laboratory Projects) grant was used to transfer technology developed by the government to the private sector.

The primary formal mechanism intended to accomplish this purpose within the Transport Canada portion of the Arctic Marine Transportation Research and Development Program has been the Marine Advisory Board consisting of representatives

nominated by industry. Prior to a reorganization in 1984, this Board did not function well as a co-ordinating mechanism for a number of reasons. Thus, for the most part, co-ordination of efforts and avoidance of duplication has had to be based primarily on informal contacts and staff knowledge of the industry's research and development work. The recent changes in the structure of this Board, together with the recommended increase in resources and efforts to keep industry informed, should overcome the problems that have been experienced.

2.4 Other Observations

A few other comments on the program structure are appropriate here in addition to the points raised by the Industy Review Panel.

The point made in the discussions of the Industry Review Panel about the prematurity of work on Emergency and Rescue Procedures draws attention to an area of study that requires special efforts. Both the joint Canada - U.S. abandon ship exercises and the Offshore Safety Task Force which reported to the EPOA/APOA* Safety Committee, identified many aspects in which equipment, services and regulations are inadequate. A major joint effort with industry seems to be required before more disasters occur. Simply increasing the level of government expenditure in this area would not guarantee feasible solutions to the problem. What appears to be required is to make it possible for the best minds from both industry and the government to work together to develop innovative and practical solutions to the problems of providing for the safety of those working in the harsh Arctic marine environment. This needs to be well planned and formally structured.

As previously noted there are five tactical objectives for which no projects have yet been initiated or planned. The Panel suggested that no work should be done under the program on 2.2 Emergency and Rescue Procedures or 3.2 Social, Economic and Ecological Impacts. For the former, the reason given was that work had to be done first to successfully identify the necessary safety and emergency equipment (2.3). (It is also true that a clear government policy on types and levels of services to be provided is needed before procedures

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* Eastcoast Petroleum Operators Association and Arctic Petrolium Operators Association. The relevant observations may be found in "Executive Summary: Offshore Safety Task Force Report to the EPOA/APOA Safety Committee", October 20, 1983.

can be established). For the latter, the reason given was that private industry has already been doing sufficient work in the area of study with financial support provided under other government programs. There are three other areas where no work has been planned under the program:

3.3 Stationary Storage Vessels
3.4 Operating Routes
3.5 General Design and Operating Information

The question of using stationary tankers for storage of petroleum in the Arctic is an important regulatory problem, and also an example of potential confusion in organizational responsibility between Transport Canada and the Canadian Oil and Gas Lands Administration (COGLA). We will return to this question a little later in considering problems of coordination of efforts in the management of the program.

Because of the lack of good hydrographic maps of the Arctic, and in order to be sure that the government can respond quickly and effectively in emergency situations, it may be necessary to restrict operating routes in the Arctic by regulations. This is not a normal practice but could be required to ensure that only known safe passages are used and that vessels can be quickly located in the event of an emergency. Because it is not a normal practice, both the feasibility and the desirability as of such a regulatory approach, as well as what routes could be safely used, need to be studied well before there is significant volume of Arctic commercial shipping. Therefore during the 1983 Evaluation, a representative of the Coast Guard sugggested that this tactical objective should be added to the program. However, in line with the comments of the panel, any work done in this area of study at the present time could be obsolete before it was used because of ever-changing knowledge and technologies. Therefore, while this is an appropriate long-term need, it should not be considered to be a tactical objective or high priority of the current program.

The question of pulling together results of the research to inform designers and operators (4.8) is primarily a matter of technology transfer. This question will be specifically addressed in Chapter 7 on Management of the Program.

2.5 Conclusion

The primary or strategic objective of the program has been to provide for safe and efficient year-round marine transportation in the Arctic while secondary or supplementary objectives were to simply improve Arctic marine

transportation, to achieve objectives in ways that are compatible with protection of the environment and contribute to national energy conservation goals, to demonstrate Canadian sovereignity in the Arctic, and to assist in the technological development of Canadian industry. The requirements to achieve these objectives have been set out as specific tactical objectives. A large number of projects and activities have been initiated to accomplish these goals.

The Industry Review Panel felt that the areas of study were essentially well chosen and observed that the level of expenditures were (just) adequate for the work to be done.

Five areas of identified needs where no work has been planned were noted. In three of these work would appear to be inappropriate at least at this time. Two others present problems which will be considered in Chapter 7.

One serious shortfall in this program and other efforts was noted. Problems of emergency, survival and rescue under severe Arctic conditions have not yet been resolved. Nor, in fact, has a clear government policy on its responsibilities been formulated. Special efforts will be needed in this area to provide for the safety of those who will be working on vessels in the Arctic winter and these need to be well planned and formally organized.

3. IMPLICATIONS OF RESULTS FOR REGULATIONS

When the Regulations under the Arctic Waters Pollution Prevention Act were prepared, directly relevant information and experience were sparse. One of the key objectives of the program has been to provide the scientific information necessary to confirm or amend these regulations. Unfortunately from the point of view of measuring program results in this area, the program has been in operation for only three and a half years. It takes much longer than this for valid information to be collected and translated into regulations. Therefore, to test results in this area a separate independent report was commissioned to examine the regulatory implication of program results to date. This chapter summarizes the scope of this work and its major observations.

3.1 Scope of Review of Regulatory Implications

This part of the work for the 1984-85 Review of the program was carried out by Mr S. Mathews. Mr. Mathews has been a leader in marine research in Canada for over 30 years and is the former head of the Institue of Marine Dynamics of the National Research Council. He was a member of the task force that originally prepared the Regulations for the Arctic Waters Pollution Prevention Act. As such, he is emminently qualified to conduct a review of the regulatory implications of the research under the program.

Mr. Mathews reviewed a large number of documents, including fifty-four reports from fifty projects. Of these reports, forty-one had at least indirect bearing on the regulations in that they improved the understanding of the problem that was being addressed by the regulations. In his judgement, thirty directly impinged on regulations in that they provided information that either confirmed the suitability of existing regulations or indicated that changes were advisable or might be necessary. Six studies gave information that appeared to be direct and conclusive enough to be acted upon immediately.

3.2 Specific Implications by Identified Needs for Knowledge

The observations from this review of the fifty projects have been organized by subject areas which, by and large match the tactical objectives of the program. The numeric identifiers for the related tactical objectives have been shown in brackets after the subject area headings.

3.2.1 Hull and Structure (1.1)

A large portion of the studies have been in this area. Most of these have been full scale measurement on vessels operating in the Arctic although there have also been important studies of other types (e.g. the development of the Aspen model). The studies indicate that the methods of calculation used for the current regulations are not adequate. A database has now been accumulated that will assist regulatory revisions. While interim changes could be made, further efforts are required to address specific questions and to accumulate more information to ensure that conclusions remain valid.

3.2.2 Load Lines, Stability and Ballasting (1.1 and 2.1)

Research results indicate a need for amendment of the Regulations in this respect. General proposals have been put forward for load lines and stability design standards for Arctic vessels and for operating procedures for loading and ballasting under Arctic conditions. While these could be put into effect, results also indicate that continuing study would be advisable.

3.2.3 Materials and Fabrication (1.2)

The studies completed have identified necessary changes in the Regulations concerning external hull plating. Draft amendments to the Regulations are now in the review process.

3.2.4 Rudders and Steering Gear (1.3)

The Regulations applicable in this area require the owners to show that the designs are adequate. The special Arctic problem here is that rudders and steering gear are particularily vulnerable when vessels are backing up to ram ice. The studies that have been completed under the program give new information that is very useful for the design of these components for Arctic operations. However, further studies are required before definitive conclusions can be drawn and more specific standards and regulations prepared.

3.2.5 Propulsors, Main Machinery and Shafting (1.4)

The studies conducted to date in this respect were conducted on a vessel whose power system was considerably in excess of the requirements for its classification under the Regulations. Since, despite being overpowered for its class, the vessel encountered conditions where its power was not sufficient, the trials demonstrate that the current regulations are inadequate in some respects for lower class vessels. Continuing studies are needed, nonetheless,

to determine precise power requirements for the various Arctic Class vessels.

3.2.6 Propellers and Ducts (1.5)

The data collected to date from voyages and sea trials demonstrate the advantages of ducted propellers in Arctic conditions. The ducts provide extra protection from ice damage and give added thrust. The possibility of ducts is not taken into account in the Regulations. The data is sufficiently conclusive that the Regulations could be amended to take into account propeller-duct thrust and the protection given to the propeller by the ducts, although some additional work is required to finalize precise amendments.

3.2.7 Crew Accomodations (1.6)

The study completed on requirements for crew accomodations on Arctic vessels showed special requirements existed because of Arctic operating conditions. Amendments to the existing shipping regulations for these vessels could be prepared.

3.2.8 Arctic Fishing Vessels (1.7 and 2.6)

The studies completed provide detailed suggestions for regulations. However, it is generally agreed that there is no need to formalize and implement such regulations at the present time.

3.2.9 Safety and Emergency Equipment and Procedures (2.2 and 2.3)

The studies conducted to date primarily demonstrate the inadequacy of current equipment and procedures under Arctic conditions but as yet provide few solutions to the severe problems of survival and rescue under such conditions. In a few cases, tests have demonstrated special equipment that must be available in the Arctic (e.g. flares that can be lit without taking gloves off). Thus some minor amendments could be made now. However, continuing study and development work is essential in this area. A clear government policy on what services will be provided is also needed to guide the search for appropriate equipment and procedures.

3.2.10 Staffing and Training (2.4)

Only preliminary work has been completed in this area. Operating experience suggests that special training and certification may be necessary for staff to operate and navigate safely in the Arctic because conditions are so different from other normal shipping areas (e.g., navigating through moving ice hazards more than navigating around fixed bottom hazards and navigating in periods of 24 hour

darkness). However, there is as yet no proven need to change existing regulations. Further study is required.

3.2.11 Operating Zones and Seasons (3.1)

Voyage data and ship trials give a great deal of relevant new information. This, together with Arctic climatological information accumulated by the Atmospheric Environment Services (A.E.S) of the Department of Environment under this and other programs, would probably affect the designated zones and seasons under the Regulations, which have remained unchanged for almost fifteen years. While the need to review the Regulations is indicated by results, a comprehensive study of all the new relevant information is required before changes could be made. The ongoing ASPEN studies appear to meet this requirement, although it is possible that they may not be making full use of A.E.S. data.

3.3 Technical Quality of Studies

Although not carried out for this purpose, Mr. Mathews review of the fifty-four reports also constituted a review of the technical quality of the research efforts. It should be noted that the reports reviewed were all for projects carried out under the auspices of Transport Canada. The research carried out for the program under the auspices of Fisheries and Oceans and the Department of the Environment is primarily aimed at improving government services rather than confirming or improving the Regulations. Therefore, the comments in this section apply only to the part of the program that is managed by Transport Canada.

On the whole the research was very well carried out and value for money was received. Most of the research was quite practical, which is to be expected given the applied orientation of the program, and this practical research was all well done. Some of the research did require highly sophisticated measurement and analysis. In a few cases work carried out of this type was not all that it could have been and the results were therefore not quite as precise and conclusive as they might have been. However, these minor weaknesses are more likely to be a reflection of marine research capabilities in Canada than attributable to Transport Canada's management of the projects. Relatively little highly sophisticated marine transportation research had been carried out in Canada prior to this program and training for this is relatively new in Canada. Thus, capabilities for conducting such sophisticated research have been a scarce resource, although this program itself should help improve Canadian technical competence for marine transportation research.

3.4 Conclusion

The program has succeeded in providing information that will assist in improving the Regulations under the Arctic Waters Pollution Prevention Act. While much of the work to date primarily provided necessary background information to understand the problems, and continuing study of most of the identified areas is essential, some specific changes could be made in the immediate future. Changes are in process for the Regulations affecting materials used for hull structures of Arctic vessels. The external expert contracted to review this area also concluded that some changes could be made at present in the Regulations affecting: (a) load lines, stability and ballasting of these vessels; (b) ship power requirements; (c) propellers and ducts; (d) crew accomodation; and (e) safety and emergency equipment. The information gathered to date can also be expected to affect several other aspects of the regulations, but continuing studies are required before precise requirements for changes in these other aspects of the Regulations can be conclusively demonstrated and appropriate changes identified.

The review of project reports carried out to identify regulatory implications of the research results also presented an opportunity to consider the technical quality of work done for projects carried out for Transport Canada under the program. In general the technical quality of the work was excellent. The few cases of minor weaknesses noted in some of the highly sophisticated measurement and analysis work are a reflection of some of the weaknesses that had existed in Canada's marine transportation research capabilities. The program is in fact helping to correct these deficiencies by offering opportunities for Canadian firms to gain more experience in this research.

4. IMPACTS ON GOVERNMENT MARINE SERVICES

The Arctic is a unique and challenging environment. Arctic electrostatic conditions present a problem for achieving (and maintaining) radio contact for communications. A large number of communication links and navigational aids are needed in such a vast area, but staffing and maintaining such links and aids over such an area with small, isolated settlements is very difficult. The combination of these problems with the severe Arctic climate poses problems for carrying out search and rescue activities or detecting and finding spilled oil. These problems would be exacerbated in winter periods of 24 hour darkness. The continuous movement and crushing-force of the ice make it impossible to use standard floating navigational markers and make it essential to use specially developed designs and types of shore structures.

In order to provide for safe, year-round navigation in Canada's Arctic waterways, the government had to develop new ways of providing infrastructure services. To do this methods of avoiding the severe Arctic electromagnetic disturbances that can prevent or sever radio Communications links were needed, as were navigational aids which would be easy to assemble, would require little operating or maintenance attention and would require as little refuelling as possible. It was necessary to learn how to design and build these and other service structures in ways that would resist damage from Arctic ice and weather. While current hydrographic maps of the Arctic were (and are) obsolete and inadequate, it would have been impossibly slow and expensive to update them using standard methods of collecting the data, because of ice cover and ice interference. New methods were also required of measuring and predicting Arctic ice, weather and sea states. Further, the government had to learn more about how to safely and effectively navigate around, or transit through, Arctic ice, both for its own ships and for the safety of commercial vessels.

In this chapter we will describe some of the improvements that have been made possible by work carried out under the program.

4.1 Power Sources for Communication Links and Navigational Aids

Providing suitable power sources for Arctic communication links and navigational beacons presents a distinct challenge. Transmitting stations and beacons tend to be in very remote locations. Delivering fuel to such locations and servicing

the power sources is very expensive. Appropriate power sources must be very reliable, energy efficient, and capable of operating at very low temperatures.

This problem was approached by first identifying three levels of power requirements. Some beacons use relatively little energy, some have moderate requirements and other facilities require quite a bit of power.

For units with low power requirements, a combination of solar photovoltaics and cold-proof batteries was tested and proven reliable. These units capture energy over the Arctic summer, store it and deliver it as needed throughout the long Arctic winter. Systems designed according to Coast Guard standards are now being used in the Arctic by the Department of National Defence. The Coast Guard has one system now operating in Resolute Bay and these systems will be used extensively in future expansions of Arctic Aids and Telecommunications.

For intermediate power requirements, a hybrid wind generator system (wind generator with a Coast Guard designed cold-start diesel or Rankine-cycle engine) has been tested and proven suitable for remote locations, with a high probability or being reliable and efficient for the Arctic. Because of the costs of monitoring such a test, these tests were run first in southern Canada. Based upon the results of the tests, a modified version has been designed and built for Arctic use, with Arctic tests to be completed by March, 1986. In the meantime the original design has been proven acceptable for remote locations in southern Canada and the test unit is being used as an operating unit in a remote location in New Brunswick.

For higher power requirements, special containerized units with automatic controls were designed, tested and proven. These units are diesel generators with full heat recovery as a source of power and heat. The diesels operate on a battery charging - shut down cycle to obtain maximum fuel economy. They are now in use in several remote locations in Canada and have also been sold for use in other countries.

4.2 Improvements in Navigational Aids

These containerized units have several other advantages in addition to fuel efficiency. They can be assembled and put into operation in a matter of days (a significant advantage considering the cost of maintaining persons to build facilities in remote Arctic sites). They have proven to be highly reliable and relatively easy to maintain.

Severe problems have been experienced in Canada with navigational aids in and around ice-infested waters. Sooner or later these have been shifted, damaged and even obliterated by the ice. These problems were expected to be

even more severe in the Arctic. Ice-crushing and resistance tests carried out under the program have provided the knowledge necessary to design, build and install facilities that will withstand these ice forces in the Arctic and other Canadian ice-infested waterways (e.g. the St. Lawrence and Great Lakes) and thus save significant amounts of money that otherwise would have to be spent on repairing and re-building these structures.

Because radar is and will continue to be a prime method of navigation in the Arctic, there is a great need for wide deployment of frequency agile radar transponder beacons (Racons). The racons, probably solar powered, must be able to operate at extremely low temperatures. In response to this need, special low temperature racons have been developed and proven under the program.

One other problem for navigational beacons is that, to conserve energy and save on wear-and-tear, they are normally turned on and off at the beginning and end of a shipping season. This has been done manually. To do this in the Arctic would entail a visit by an icebreaker, and, possibly, a helicopter, to get the staff person to the site. This could be very expensive, costing thousands of dollars a year per navigational aid. Moreover ice breakers might not be available when needed. To solve this problem, a special 365 day timer that allows these nav-aids to turn themselves on and off, was designed, developed, tested and proven under the program. The long term savings from this will amount to hundreds of thousands of dollars, to say nothing of the fact that the timer will allow the beacons to be turned on and off when they should be, rather than when (or if) a tender is available.

4.3 Improvements in Communications Facilities

One of the first steps taken early in the start of the program was to identify some of the requirements for communications if the volume of marine traffic was to be increased and navigation was to carry on throughout the whole year. An engineering survey of sites and facilities provided the knowledge required to upgrade antenna systems in order to provide the coverage throughout the Arctic that will be needed. This upgrading is now in process.

In terms of development of new equipment suitable for use in the Arctic, a specially designed communications console for Coast Guard radio stations there has been tested and proven.

A great deal of progress has been made on other developments essential for effective Arctic communication and navigation (e.g. equipment and software for downlinking ice navigational

data to ships from satellites and aeroplanes and for automatic mutual shifting of radio frequencies to overcome Arctic electrostatic disturbances). However, because of the scope and complexity of the problems, continuing work is needed here.

4.4 Ice Measurement and Mapping

In order to navigate safely in the Arctic, it is essential to know the thickness of surrounding ice and to be able to differentiate between the softer first-year (salt water) ice and much harder multi-year ice (where the salt has been leached out). Methods of remote measurement and identification had to be developed.

Two developments have proven very useful here. First, an airborne laser profilometer was developed, tested, and proven. It is now in regular use both to provide the Atmosphere Information Service with general ice information and to provide vessels with specific information on surrounding ice conditions. Second, the necessary software was developed for interpreting satelite passive microwave readings and providing large scale ice maps (% coverage, type, thickness) in real time to direct tactical, as well as strategic, navigation. Unfortunately communications with the American satellite that was collecting this microwave data were shut down quite recently. However in a year or so a new satellite will be in orbit that will collect even better microwave data and allow more detailed maps to be produced with a higher degree of resolution.

4.5 Hydrographic Mapping

One of the problems for navigation in the Arctic has been that the hydrographic charts were prepared a long time ago using methods that are now known to be inaccurate. Unfortunately, it would cost for too much money and take well over fifty years to collect the information necessary to upgrade and update these charts by conventional methods.

One short-term solution has been developed, tested and is ready for use. This is a specially designed boom with multiple underwater acoustic scanners, a data-logging subsystem and a post-processing subsystem. The boom can be attached to a launch. It allows a 30 meter swath to be covered with each pass of the system, given 100% bottom coverage in from 7 to 100 meters of depth. It can be used to scan potential navigational channels quickly and ensure that there is sufficient clearance for safe passage.

A longer term solution has been developed, but is still being tested and refined. This is an Autonomous Remote Controlled Submersible (ARCS) which can move about under the ice and collect and record hydrographic data automatically.

4.6 Weather, Ice and Sea-state Reports and Forecasts

When the Arctic Marine Transporation R&D Program was started, the knowledge-base about Arctic weather, ice and sea-states and the ability to provide reliable forecasts of these conditions, were inadequate for the needs for safe Arctic navigation. The program has provided the resources to allow greater accumulation of necessary knowledge and to allow the continuous improvement of Arctic conditions forecasting systems. Significant improvements have been made in the accumulation of historic and ground-truthed knowledge and in the attainable degree of accuracy of reports and forecasts.

4.7 Pollution Detection and Control

The geography of the Arctic presents special problems for the detection and control of oil spills. To the problem of a vast area with many isolated reaches is added the problem that oil slicks can move around and under the ice. These problems have been addressed under several government programs.

A number of contributions towards resolving these problems have been made from projects under the Arctic Marine Transportation R&D Program. The necessary software has been developed to provide a model and system for tracking oil slick movements in and around ice. Some work was done on testing and standardizing light-weight air-transportable containment booms. One project delineated the practical problems of using airborne ignitors to burn off pools of oil that form around the ice and shorelines after an oil spill. These ignitors had been previously developed as a solution to disposal of slicks in the Arctic. The practical problem is the number of separate oil pools that are likely to form from one spill (2,500 to 10,000) and therefore the number of ignitors that have to be accurately placed to dispose of any one spill. Work is now proceeding under the program to develop laser ignition techniques and make them practical for Arctic use.

As noted earlier, this work has been closely co-ordinated with industry. The petroleum industry's research association COOSRA has also carried out extensive research to solve problems in this area.

4.8 Ice Transiting and Icebreaking

A wide variety of projects under the program have been designed to improve ice transiting and icebreaking methods. The results have had both regulatory and operational implications. The knowledge gained has allowed the improvement of bow designs for icebreaking and the development of optimal techniques for ice ramming. Projects have tested and proven special coatings that prevent ice build-up on the hulls and have identified the proper types of steel to be used in Arctic vessels to prevent low-temperature brittle fracture.

One piece of equipment developed under the program is being included in the icebreakers now under construction. This is the NAWS Hull Warning System which continuously measures stresses on hull structures of vessels ramming through and breaking ice, and warns when these stresses are approaching the maximum tolerance level for the construction of the ship. The use of this system will help prevent damages, lost time and costly repairs.

4.9 Conclusion

In this chapter we have reviewed the impacts that the Arctic Marine Transportation Research and Development Program has already had, or will have in the near future, on the ability of the government to provide the marine transportaiton services fcr which it is, or would be, responsible in Canada's Arctic waters. A large number of problems in the areas of communications, navigational aids, provision of environmental information and forecasts, identification of safe channels for navigation, tracking, controlling and disposing of oil spills, and ice transiting and ice breaking have been addressed. A number of these have been resolved. For others, the knowledge, systems or products necessary to resolve them are being developed.

The program has been highly productive. Although continuing work is required, in a relatively short period of time the program has developed solutions to many of the problems faced by the government in preparing to provide infrastructure services to year-round shipping in Canada's Arctic waterways.

5. INDUSTRIAL IMPACTS

Although industrial development is not the primary goal of the program, it has been a significant consideration in the selection of areas of work and in the selection of project activities. The program has had significant impacts on the Canadian marine transportation industry both in the development of Canadian technology and technological expertise and in the development of specific marketable products and services. In this chapter we will outline these impacts and consider how the program contributed to these developments.

5.1 Development of Technological Expertise

The Canadian marine transportation industry faces a number of structural problems in attempting to develop and maintain technological expertise.

In the first place the industry has been a "boom or bust" industry for a long time. When times are good all the expertise available may be needed to solve immediate production problems. When times are bad, expenses are "pared to the bone" and research work that might develop new expertise is considered expendable.

Moreover the units of production are quite large and, relatively speaking, few in number. Innovations can be copied by others before many units are produced. Thus the firm that does take the lead in making an innovation gains an advantage for relatively few units of production. Added to this, the Canadian marine transportation industry supplies a relatively small proportion of Canada's total needs for shipping and vessels since most trans-ocean shipping is carried by vessels operated and built in other countries.

The Canadian shipbuilding industry also suffers from Canadian geography. Ship repairing facilities have to be spread out to be available at major points on marine routes. Shipbuilding and ship repairing facilities are, for the most part, one and the same. There is greater distance between these facilities in eastern Canada, let alone Canada as a whole, than between the shipyards of Europe or between the shipyards on the Asiatic Pacific rim. This makes it very difficult to develop a concentrated and sophisticated supply industry for vessel components and equipment. It also makes it very difficult for Canadian marine technologists and engineers to maintain contact with each other and help develop Canadian expertise through exchange of information and experience.

Another problem is that the shipbuilding industry is an engineering industry. Innovations are more likely to be incremental improvements than whole new products, to be an intregal part of designing a vessel for a particular customer rather than the result of a clearly identifiable research project. Because of this, firms in the marine transportation industry can seldom qualify for assistance from the government programs (like the Industrial Research Assistance Program of NRC) that are intended to help the development of Canadian technology and technical expertise.

Given these structural problems, there appears to be a very definite need for a special, government funded, nationally focused program which assists in the development of Canadian marine transporation technological expertise. Without it the Canadian industry is likely to become less and less able to compete in its own home market, let alone international markets.

One of the strong points of support for the Arctic Marine Transportation R&D Program that emerged again and again in the visits by the project team to firms across the country is that it has provided a basis for the development and maintenance of Canadian expertise. Providing marine transportation through ice-infested waters like the Arctic is a special Canadian problem. It is one area where Canada has an acknowledged technological lead and where the services of Canadian firms are actively sought out by foreign firms. Admittedly this edge was initially provided through the research carried out by petroleum companies interested in the Arctic. However this private-sector research activity has been severely curtailed because of the world oil situation. In the meantime the Arctic Marine Transportation R&D Program came into existence and allowed the maintenance of expertise that had been developed and the development of new experts and areas of expertise. Even firms that had not themselves participated in and benefited directly from the program, acknowledged this contribution and stressed its importance to Canada and Canadian industry.

5.2 Technological Development

Marine Transportation is not in itself a single technology. Rather it uses, and impacts on, a large number of different industrial technologies. Thus the program has assisted in the development of a wide range of technologies in Canada. While some of these are limited to the Arctic or to marine transportation, others have implications far beyond these areas. In this section we will list and describe some of these impacts.

5.2.1 Structural Steel for Low-temperature Conditions

Tests carried out under the program have provided a great deal of new information on the failure of steels through brittle fracture under sustained low-temperature conditions. It has allowed Canadian steel companies to identify, and further develop, steels which will resist these conditions. This knowledge provides advantages not only for the building of Arctic vessels, but also for the building of other structures that will have to withstand sustained low temperature conditions.

5.2.2 Arctic Ship Design

The data collected under the program has been invaluable for identifying optimum parameters for design of Arctic vessels. Comprehensive information has been gathered on alternative bow shapes, hull materials and structural strengths, and many other critical factors. Canada and Canadians now have unique knowledge and a technical edge in the design of vessels for Arctic type operations.

5.2.3 Icebreaking

One very important factor in the design of Arctic vessels is icebreaking capabilities. The program has provided Canadians with unique knowledge not only of how to design ships for more effective icebreaking but also of how to operate them for maximum effectiveness and efficiency. While icebreaking requirements are most severe in the Arctic, this knowledge is applicable to many other areas of Canada and the world.

In fact one of the projects carried out in the program has not proved fruitful to date for Arctic icebreaking but does have applications elsewhere. The Air-Cushion Icebreaking Bow is a Canadian innovation whose development was supported under the project. It involves attaching the modified equivalent of an air-cushion vehicle to the bow of an ice-breaker. The thrusts and vibrations, set up by the air-cushion, fracture the ice and allow the icebreaker to continue to move forward at a much higher average speed than conventional icebreakers. While this may not work with ice of the thickness and strength regularly found in the Arctic, it has proved to be effective and efficient for harbour clearance at Thunder Bay. It therefore has potential for application in many similar situations.

5.2.4 Instrumentation and Modelling

Before effective data could be collected and analyzed on the performance of various features of Arctic vessels it was first necessary to develop appropriate instrumentation to measures hull stresses etc. and the computer models that could use this data and simulate related stress conditions to extend the utility of the real-world data. Contracts to develop these improvements were let to various firms, who thereby extended their own technological knowledge on instrumentation and computer modelling and improved Canada's technological knowledge and capabilities.

5.2.5 Submersibles

Canada is a leading world supplier of tethered submersibles* for subsea exploration and construction. The program has encouraged and supported the development in Canada of the technology of untethered unmanned submersibles for subsea mapping and exploration.

The key project here has been the ARCS (Autonomous Remote Controlled Submersible) project. Under this project the Canadian Hydrographic Service has supported the development and testing of a remote controlled submersible for mapping the sea-bottom under ice. Such autonomous subsea vehicles have many other potential applications and have advantages in many situations over tethered and manned vessels. Strong interest in this type of submersible has already been expressed to the Canadian manufacturer by many firms from around the world who are involved in subsea exploration for mining.

A spin-off from this has been the completion of the development of the "Dolphin". The ARCS operates mainly on its own from pre-programmed instructions. It normally maintains contact with a base point using sonar, but operates on its own to avoid obstacles and can find its way back "home" even when this contact has been interrupted. The Dolphin does not operate on its own but is a satellite vessel under continuous control from another vessel. The main structure is submersed to avoid effects of waves and winds, but radio contact with the main vessel for control and recording of data is maintained through a snorkel antenna. The Bedford Institute first began experiments with radio controlled satellite survey vessels in 1965, but these

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* i.e. submersible equipment that is controlled through cables running between the equipment and a controlling surface vessel.

experiments were abandoned as unfruitful in 1971. When the ARCS project was underway, the thought emerged that much of the technology being used to design and construct the ARCS could also be used to build satellite hydrographic survey vessels. Thus the project was re-initiated and has proved very successful. These satelite vessels are also likely to have many applications beyond hydrographic mapping.

5.2.6 Alternative Power Sources for Remote Locations

The contribution of the program here has been to demonstrate the practicality of alternative power sources. Solar photo-voltaics and wind were demonstrated to be effective and efficient alternatives to gasoline, diesel and batteries that need to be regularly replaced in remote locations. Both are now being used in appropriate situations by the government as energy sources.

5.2.7 Radar, Lidar and Passive Microwaves

The program has also done a great deal to advance the application of radar, lidar (lasar radar) and passive microwave technology. Improvements have been made in the use of radar to identify ice and ice conditions, a technology that is important for navigating in any ice-infested waters, not just the Arctic. Lidar techniques for ice mapping and measuring water depths have been developed and ground-truthed. Because of the accuracy of lidar, these basic techniques are likely to find other navigational uses (e.g. navigation in fog through close waters and canals). Computer-aided techniques for using satellite passive microwave readings to identify and map ice conditions, sea-state (waves) and cloud conditions have been developed. Again the potential uses of this technology go beyond the Arctic. Further the computer technology of interpreting satelite passive microwave data is likely to pave the way for ship-based passive microwave equipment that will help detect significant hazards.

5.2.8 Weather, Ice and Sea-state Forecasting

These improvements in radar, lidar and passive microwave technology have improved Canadian capabilities to monitor weather, ice and sea states in the Arctic and elsewhere. At the same time the information gathered under the program using these devices, together with improvements made under program projects to the computer models that use this data in a predictive mode, have resulted in more accurate forecasts of Arctic weather, ice and sea states. In fact not only have these efforts helped develop Canada's environmental forecasting technology, they have, as we will see in the next

part of this chapter, lead to the development of specific marketable services for Canadian firms.

5.3 Development of Products and Services

The research and development work that leads to new, marketable products and services can be thought of as a number of sometimes iterative steps. In fairly simplified terms these steps can be said to be: (1) the gathering of systematic and precise data from laboratory experiments and natural situations; (2) design; (3) building of proto-types; (4) field testing; and (5) operational demonstration. One of the advantages to industry of the Arctic Marine Transportation R&D Program has been that it can support all five of these steps. However the work of the first type supported under the program has so far lead only to general technological improvements. The work that has lead to specific marketable products and services has been of the last four types and, in some cases, only the last two types. In this section we will first identify products and services developed to date and the type of contribution made in each case, and then note some developments in process.

5.3.1 Containerized Nav-Aids

The most commercially successful project so far under the program has been the development of containerized NAV-AIDS. These are essentially pre-fabricated self-contained power units with appropriate beacons. The program supported the initial design work, the building of a proto-type, field-testing and demonstration. The company was visited and confirmed the importance to them of this full range of support. They had by then sold over $1,000,000 worth of these units in Canada and abroad. While a few components for these units have to be imported, over 85% of the content by value is Canadian.

5.3.2 Marine Conditions Forecast Systems

As a result of work conducted under the program, one Canadian company was able to develop a marine conditions forecasting system which supplements information and forecasts routinely supplied by Atmospheric Environment Services. This service is now sold commercially to Canadian and other firms but the company was not able to report the value of the sales which have resulted to date.

5.3.3 Oil Spill Trajectories

This same firm, under another contract, was assisted in developing models for projecting the trajectories of oil

spills to help track them. This service is also now offerred commercially.

5.3.4 Satellite Microwave Ice Maps

Another firm was assisted under the program to develop the capability of transforming satellite passive microwave readings into ice-condition maps of areas (i.e. maps which indicate the proportion of an area covered by ice, the average and range of thickness and the proportion of hard multi-year ice). This can be communicated to onboard receiving units which produce the maps right on the ships. The information would be recent enough that it can be used for continual planning of routes through ice infested waters. Unfortunately just as the company had developed this capability far enough that it had several firms interested in the service, the Americans, whose satellite was supplying the microwave readings, shut off the unit that was receiving the data from the satellite. A new satellite will be supplying this type of data (with a higher degree of resolution) in less than two years time. The company expects to have several customers when this data is available.

5.3.5 Laser Profilometer

Support from the program allowed significant development in a very new technological area - lidar (lasar radar). Laser range finding is much more precise that conventional microwave radar. The specific product developed, a Laser Profilometer, was developed for identifying and measuring ice conditions from an aeroplane but can also perform other tasks such as water depth measurement from aeroplanes. The company estimates the market for this product at $100,000 per year but expects many spin-offs products with wider potential. The program gave crucial support for design, building a proto-type, testing and demonstration. The equipment is now used by the government in an operational mode.

5.3.6 NAWS Hull-Stress Warning System

Another product where support from the program was crucial for full development, is the NAWS Hull-Stress Warning System. This instrumentation system was developed from start to finish with government funds and the government now owns the patent. It is licensed to a Canadian firm for general marketing. As previously noted, it has already been specified as standard equipment for the new generation of Arctic icebreakers under construction.

5.3.7 Developments in Process

In addition to these products where development work has been successfully completed, there are several innovative products whose development is being supported by the program. Among these are the ARCS (Autonomous Remote Controlled Submersible) and the ACIB (Air-Cushion Icebreaking Bow) discussed earlier in this chapter, and two others: externally-pressured stern tube bearings and laser ignitors for burning off oil spills.

The stern tube bearings on ships where the shafts exit from the hull are subjected to severe destructive forces. These forces are exacerbated by long Arctic voyages through ice. Vessel breakdowns in the Arctic, where there are no repair facilities and, in any event, repair could be exceedingly difficult because of environmental conditions, could present severe problems. One method of reducing the destructive impact of these forces and the probability of breakdown, is to support the shaft so that it in effect floats on pressurized jets of water. This concept is being developed for commercial application under the program and is expected to lead to specific marketable products.

The most appropriate way of disposing of oil spills in the Arctic is to burn them as they sit on the water. The problem is to ignite them while they sit on the water in and around ice. Several years ago, under a different government program, an airborne explosive ignitor was developed and proven effective. One practical problem was noted and subsequently investigated under this program. In the Arctic environment the oil tends to fracture into a large number of small pools. It was thus found that it could take several thousands of ignitors just to burn off the oil from one spill. Transporting, storing and placing this number of explosive ignitors would present severe practical problems. Therefore a new solutions to the ignition problem was looked for.

In searching for alternative solutions to this problem, it was found that a company in the United States had developed an alternative method using a Canadian-built laser. The basic know-how was purchased from the American firm. This technology is being tested and finalized in Canada with funding from the Arctic Marine Transportation R&D Program and is expected to be licensed for production here.

5.4 Conclusion

Although the program was not designed as an industry assistance program, it has had many industrial benefits to date and is expected to continue providing these spin-offs. The program has had a significant impact on Canadian marine transportation expertise, has helped improve many aspects of Canadian technology and has assisted in the development of several marketable products and services. Even though the primary purpose of the program has been to assist the government in carrying out its responsibilities, a significant portion of the costs can be expected to be returned to Canadians as industrial benefits.

6. FUTURE ALTERNATIVES

As we have seen in the last three chapters, the program has already accomplished a great deal. However, the program now has only another year to run because program and funding approval expire at the end of March, 1986. Thus one of the questions that needs to be addressed is what should happen beyond this date.

In order to explore this question, it is necessary to consider the potential benefits and disbenefits of alternatives. Four different alternatives were examined.

The first option is simply to let the program expire. Given that the program was initially planned to achieve certain results in a specified timeframe, this alternative must be considered. However it must also be noted that the program was only funded at about a half of the proposed cost and therefore cannot be expected to achieve all necessary results in the first five years.

The simplest and most obvious alternative to letting the program expire is to carry on Arctic-focused marine transportation research. The need to solve Arctic marine problems still exists and the benefits from attacking this technologically challenging area have been proven. However, the degree of urgency in solving Arctic problems has lessened since the program was approved, while other marine transportation problems may have become equally important. Thus in addition to a second alternative of continuing with a new program focused exclusively on Arctic problems, two other alternatives were considered which would broaden the scope of problems to be addressed.

Many of the problems of marine transporation in Canada's Arctic are problems of navigating and providing marine services in ice-infested waters. These problems are also faced in other major Canadian waters. While neither the solution to the problems, nor the precise nature of the research necessary to develop these solutions, are identical from one area to the other, there is a great deal of overlap. Thus, one logical way to broaden the scope of the program is to expand it to address general problems of Canada's ice-infested waterways as well as specific Arctic problems. This was the third alternative considered.

Finally, this program has been the only extensive government effort aimed at solving Canadian problems of marine transportation and at assisting the technological development of Canada's marine transportation industry. The question arises, therefore, as to whether or not it would be more

appropriate to have a general marine transportation research and development program and to address Arctic problems within this framework. The fourth alternative considered was to have such a general program with Arctic problems as but one focus within it.

The first two alternatives are direct obverses. The benefits of one are the disbenefits of the other and vice-versa. We will therefore first consider these alternatives together and then consider alternatives three and four in order.

All four alternatives were reviewed in three steps. First, selected firms across the country were consulted by direct interviews and the members of the Canadian Shipbuilding and Ship Repairing Association were asked, by their president, to make written comments. Next, both documents and staff from Transport Canada were consulted to identify perceived needs for continuing research. Finally, a cross section of Canadian marine industry experts were invited to sit as an Industry Review Panel to discuss this and other materials, and draw their own conclusions.

6.1 Needs and Benefits of Continuing Arctic Research

Several of the company representatives interviewed in the field trips specifically mentioned that they considered the program to have been successful and that year-round marine transportation in Canada's Arctic waterways was now, or soon would be, feasible, because of the work done under the program. However, they did not draw the conclusion that there was no need for continuing Arctic research.

In the first place, even though feasible solutions have been found to many of the problems that existed at the start of the program, this does not mean that these are optimal solutions. Year-round Arctic marine transportation might be theoretically possible in the near future, but a great deal remains to be learned about how to provide effective and efficient marine transportation and services. Further, as we have already noted earlier in this report, it is doubtful that this could yet be done with full regard for safety because effective and practical methods have yet to be devised of coping with emergency situations. Available lifesaving and survival equipment are not adequate for the Arctic winter environment. Thus, there will be continuing needs for research and development work.

A number of specific areas of need were identified in the consultations with industrial representatives and government personnel. The continuing needs for research and development

work for safety and emergency equipment and procedures has already been discussed. Other areas include:

(a) Structural Steel and Welding: While much progress has been made in identifying steels that will withstand the continuous low temperatures of the Arctic, some work remains to be done. Further, welding and fabrication techniques are not yet adequate. There are still special corrosion and brittle-fracture weld problems that need to be solved. (See Appendix A, response from Stelco.)

(b) Ice Management: Two significant unresolved problems were identified here. Much of the ice that is broken is pushed under the surrounding icefield. Over a period of time the continued breaking and refreezing of channels could cause severe problems through the build-up of extra thick ridges, but because the volume of traffic in the Arctic has been relatively light, the precise nature and degree of this problem remains unknown. Under the severe conditions of the Arctic winter, the winds and spray around a wharf lead to the development of large ice bustles, which make it very difficult to get vessels near the wharf. Many theoretical solutions have been proposed (e.g. simply using the ice around the wharf as additional wharf space) but significant work will be required to identify which, if any, of these solutions is the most practical.

(c) Ice Properties and Ice Occurrence Statistics: While a great deal of useful information has been accumulated since the start of the program, much remains to be learned about the formation and movement of ice in specific areas of the Arctic in order to assist safe and efficient navigation in these waters. Of particular concern in some areas is how to predict and control the movement of those very irregular objects, icebergs, and how to predict the movement of ice packs throughout the Arctic.

(d) Remote and Ship-based Sensing of Ice and Icebergs: Similarily, while a great deal of progress has been made in the techniques of determining what kind of ice is where, this knowledge is not yet accurate enough that efforts can be relaxed. Much remains to be done, especially to adapt successful aeroplane and satellite methods of identifying ice types, thickness and coverage to the more demanding

requirements of on-board identification of nearby ice hazards. As previously mentioned, the necessary equipment and software for communications between aeroplanes or satellites and vessels in the Arctic are still under development.

(e) Arctic Navigation: Continuous darkness, winds and ice present special physical and psychological navigational challenges and necessitate different approaches to navigation than can be employed in other waters. Specific techniques and procedures, which recognize Arctic constraints and stresses, have to be formalized so that they can be learned and used by Arctic crews. While some work in this respect can be done at present, it would be better if most of it were done closer to the time when major expansion in the volume of Arctic traffic can be expected. Otherwise, as noted by members of the Industry Review Panel, the techniques and procedures codified and taught would be out of date and not in line with continuing experience and research.

(f) Regulatory Monitoring and Upgrading: Finally, even though the knowledge accumulated in program so far, and that will be accumulated in the final year for which approval has been given, will allow significant improvements of the Regulations affecting Arctic shipping, the knowledge will not be complete and the Regulations will not be perfect. Thus continuing research will be needed to monitor and analyse operating experience and to address any noted problems.

Some new areas for research were also suggested in the various consultations.

One firm suggested that work should be done to identify the most appropriate alloys for Arctic propellers. These have to withstand cold temperatures and severe ice impacts. Alloys have been developed which absorb impacts. Work needs to be done to combine these developments with cold temperature effects.

Much of the work down so far has been done to develop vessels that will operate safely and effectively in Arctic conditions. As these efforts become more and more successful, work will be needed to improve the energy efficiency of such vessels, especially considering the costs of refuelling vessels in the Arctic (or, alternatively, having them carry sufficient fuel supplies and emergency

reserves themselves for complete voyages and the full range of problems they can encounter).

The methods of supply now used in the Arctic have been developed for a situation of relatively low volume. As the Arctic develops and volume increases, there will be a need to explore alternative cargo delivery systems (including ship to shore transfer of cargo), to improve speed and efficiency and to handle delivery of some of the large equipment needed by the resource industries. The federal government will have to ensure that all port facilities meet the requirements of TERMPOL (an international code of recommended standards for the prevention of pollution in marine terminal systems). Further, deliveries will have to be made more than once or twice a year.

There are also some unresolved problems in transporting oil resources to shore. While much of the near-shore oil and gas will probably move to southern Canada through pipelines, it will first have to be brought to shore. This could involve floating storage and shuttle tankers or an undersea pipeline. The former is clearly a marine problem but even the latter involves marine problems. Undersea pipelines have to be laid and serviced from ships. The whole area of how to do so safely and efficiently in the presence of ice needs to be explored.

One of the research needs mentioned by several firms, and in the 1983 Evaluation, is the need for research with larger and higher-class Arctic vessels (i.e. vessels which are much stronger and more powerful). While the MV Arctic has been extremely useful for research purposes, vessels that operate year-round in the Arctic will have to be much higher Arctic class vessels and are likely to be much, much larger (e.g. LNG tankers). There are severe limits to the reliability of extrapolating the data on structural effects of Arctic conditions from the "MV Arctic", and other vessels now operating in the Arctic, to much higher class and much larger ships.

However, the "MV Arctic" is currently being upgraded from a Class II to a Class IV vessel (Class X is the highest class in the current regulations). The Industry Review Panel, in considering this issue, felt that the "MV Arctic", so modified, will meet the immediately forseeable needs for research in this respect. While all the interested parties do not agree with this conclusion, at least this does mean that continued research funding will be necessary to take advantage of these changes and provide futher insights into the design of vessels which might, in the long run, operate year-round in the Arctic.

Thus we can conclude that there are clearly identifiable needs for continuing research on Arctic marine transportation beyond the end of 1985-86 fiscal year.

The major advantage in continuing government-supported research in this area is that these practical needs would be addressed with, given the results to date in the program, a high probability of direct success and significant industrial spin-offs. The major disadvantage is the fact that this would require continuing government expenditures in an era of constraint and cut-backs. If the program funding for the three departments now involved were to continue at its present level, the cost would be about $6,000,000 and 14 PY's per year.

The obverse of this, is that the major advantage in not continuing this government supported research would be a "saving" of $6,000,000 and 14 PY's per year (less industrial spin-off benefits not realized). The major disadvantage is that the problems identified would not be addressed and would not be resolved. While some might think that if government did not pay the cost of carrying out this work, industry would have to pick it up, the problems noted are either too general or too directly related to the government's responsibilities for this to be a reasonable expectation for much, if any, of this work. Individual firms are unlikely to fund research, however important to the industry as a whole, unless they can see a strong likelihood of short-term pay-off to themselves. They are certainly unlikely to fund research which primarily assists the government to carry out its responsibilities.

Another disadvantage is that the technological edge that Canada has built up for dealing with the Arctic would soon disappear. Other countries which have significant ongoing Arctic marine research programs (Germany, Finland, Japan, the United States) would pull ahead of Canada on all relevant technological fronts. Those who have become Arctic marine experts in Canada would have to employ their expertise elsewhere or lose it.

In considering this benefit of the program, the Industry Review Panel members generally agreed that the program should not be continued simply to keep these experts employed in Canada. It should not become a make-work program. However, sufficient real needs for research and development work have been identified that a continuing program would not be a make-work program. A distinct advantage of continuing it at this time is that it would continue to give the Canadian marine industry a technical edge and would help to keep intact the technological expertise that has been developed.

6.2 Ice-infested Waters Research Option

Almost all the firms visited from coast to coast agreed on the necessity for continued government support for Arctic marine transportation research in Canada in order to keep Canada's technological lead in this specialized area of natural interest to Canada. The exception to this was the strong case put forward (primarily, but not exclusively, by East-Coast interests) for research and development work to solve ice-related problems on the East-Coast. However, addressing these East-Coast problems was not really seen as a replacement for Arctic-focused research, but rather as a logical extension to it.

The case put forward was based first on the fact that the off-shore oil will be put into volume production on the East-Coast long before there is significant production from the Arctic. Yet few of the problems of dealing with ice and icebergs have been adequately resolved. Further, finds to date indicate that the Labrador coast is likely to be more productive than the Arctic. Before this can happen, however, the problems of drilling and maintaining oil wells in the midst of the moving ice pack that hovers along the Labrador coast for a large part of the year, will first have to be overcome. Finally, major oil spills on the east coast would cause more immediate ecological, economic and political problems than an Arctic spill.

Thus the claim was made by some companies that solving ice-related marine transportation problems for Canada's east coast is more important at the moment than solving Arctic problems. Given their economic importance to Canada and the volume of traffic they now handle, a similar case could be put for the importance of addressing ice-related transportation problems in the lower St. Lawrence and the Great Lakes.

These ice-related problems are similar, but not identical to, Arctic ice problems. In fact there has already been beneficial spin-offs between areas. Some of the computer models used for meteorological forecasting and tracking oil spills in the Arctic are modified versions of models developed for the East Coast. The satellite passive microwave technology developed for providing ice maps of the Arctic also provides ice maps for the East Coast. The Air Cushion Icebreaking Bow (ACIB), whose development was supported by the Arctic program, has proved effective for the Great Lakes but not (yet?) for the Arctic. The work on ice crushing forces done under the program will help solve some problems experienced along the St. Lawrence and in the Great

Lakes, where navigational structures were being regularily damaged by ice.

The Arctic poses some additional challenges because of its severe winter conditions, including weeks without sunlight at all. These problems need to be addressed as well as the ones posed by ice. Thus the proposal is not to replace the Arctic focus which has proved so productive, but to supplement it and recognize directly the need to address problems of Arctic-like conditions wherever they occur in Canadian waters.

The Industry Review Panel agreed with this perspective in their discussions, but in their recommendations only included the addition of east-coast ice-related research because of the priority of solving these problems to allow new development. The evaluators do not concur with this restriction but judge that if the program scope is to be expanded, the program should examine problems of marine transportation under Arctic-type conditions wherever they occur in Canadian waters.

6.3 General Marine Research Option

The most extensive option examined was the alternative of having a very broad program of marine transportation research that would include research into specific Arctic problems. This possibility was discussed in the field trips and also with the Industry Review Panel.

In general, the types of general marine transportation research needs identified in the discussions with company personnel across Canada were quite broad and quite different from the more specific Arctic requirements.

It was noted in these various discussions that significant changes were occurring in the operation and construction of ships which might present opportunities for Canada to expand its marine industry. With the combination of higher real fuel costs and hi-tech ship operations, labour is no longer the dominant cost of ship operations. Further, innovative design and equipment are becoming more important than basic price in the operating cost equation, at least for a significant part of the market that wants specialized vessels. Moreover ship building methods are becoming capital intensive with newer building methods; this significantly changes the relationship between wage rates and construction costs. While the international shipbuilding industry is currently undergoing very hard times, in five to ten years from now it should be booming to replace worn-out and obsolete vessels.

These and other factors (e.g. the fact that Canada already has world-class metal and hi-tech industries and world-class ship design capabilities) provide Canada with a theoretical opportunity. However, various types of research would be needed before this would become a practical opportunity. In the first place there would have to be extensive market and cost research done to identify the conditions under which Canada could compete effectively in specific segments of the market. A second need would be manpower requirements research to ensure that Canada could supply persons with precisely the right types of trained abilities to build and operate hi-tech ships effectively and efficiently. The Canadian industry and/or government would have to invest in design research for fuel-efficient vessels and help develop the concepts and equipment for specialized hi-tech operations. Included in this would be studies to help change the approach that has been taken where ships have been designed on behalf of owners and therefore have been designed for optimal operation rather than efficient shipbuilding; much work is needed to also optimize these designs for construction. Finally there would need to be a continuing support for productivity improvement research.

While these studies might prove benefical for Canada, they are very different from the type of research required to address problems of marine transportation in the Arctic and other similar waters. The two types of research would not fit together in one program.

Further the Industry Review Panel felt strongly that the research into the specific Canadian problems of the Arctic and Arctic-type conditions would be much more likely to pay off and would give Canada special areas of expertise. The Panel did, however, identify one area of general marine transportation research which it felt the government should be involved in. It recommended that the government should undertake general regulatory research (a) to ensure that specific marine regulations really are necessary and (b) to develop methods of regulatory ship inspection using modern techniques that would be less costly and problematic for ship owners than current methods. Involved in this latter point is the fact that some current methods of inspection require costly and time consuming dis-assembly. It should be possible to adapt modern sound and x-ray scanning techniques for these purposes.

6.4 Conclusion

Although the Artic Marine Transportation Research and Development Program has been highly successful and, in the opinion of many industry experts interviewed, will probably have made year-round Arctic marine transportation feasible

by the time it comes to the end of its approved funding in March, 1986, there will be continuing needs for such efforts after that time to improve the effectiveness, efficiency and safety of such operations. There would also be continuing industrial benefits from such a program.

Arctic-type conditions also pose problems for marine transportation and services in other major Canadian waters. These problems are closely related to those found in the Arctic and could readily be studied with Arctic problems under the same program. In fact given the importance of these other areas to Canada, it would be advisable to do so.

However, the program should not be broadened to the extent that this Arctic and Arctic-type conditions research became simply one component of a general marine transportation R&D program. The requirements are quite different and the advantages that have resulted from a focus on special Canadian problems would be lost.

To be effective, the research and development program to address problems of marine transportation in the Arctic and other ice-infested waters would have to be supported with government funding. The nature of the industry and its products is such that much of the pay-off for innovation goes to organizations other than the one who does the research and development work. Moreover most of the work to be done addresses areas of government responsibility. It would be unrealistic to expect industrial firms to initiate and fund work intended primarily to assist the government to meet its responsibilities for providing appropriate regulations and infrastructure services.

7. MANAGEMENT OF THE PROGRAM

In order to be certain of achieving objectives, a program must be both well designed and well managed. The 1983 Evaluation found that in general the program was being well managed at the project level but expressed some concerns with the lack of information for effective central co-ordination of the program and with the lack of resources to ensure effective transfer to Canadian industry of technology developed under the program. The Industry Review Panel also made some recommendations concerning the management of the program. In this chapter we will follow-up on what has or has not happened as a result of the observations made in 1983 and consider the recommendations made by the Industry Review Panel that affect the management of the program. At the conclusion of the chapter we will consider what approaches might be used in future evaluations.

7.1 Central Information and Co-ordination

The 1983 Evaluation observed that as a response to lack of staff in the central co-ordination unit, management of the program had to be highly decentralized. This delegation of responsibilities had had beneficial effects in allowing flexibility and innovativeness at the project management level. However, lack of communication of progress and results to the central coordination unit made it extremely difficult for central management to know whether the program as a whole was on target, where there might be problems that required corrective actions or what directions ought to be taken in future work. The recommendation was made that "as soon as possible central records (and the system for the records) be upgraded to make central planning, monitoring and co-ordination possible".

A few steps have been taken to implement this recommendation. The Coast Guard has installed their own project information system from which they supply quarterly reports to the central coordination unit. But this information, as with other information received, is not timely. As a result, the central records are basically historical records, not necessarily by design, but certainly by the time that most information on projects is received and entered. In fact is would appear that central co-ordination has to make a great deal of effort to get the information they do finally manage to receive on projects managed within Transport Canada, while very little information is kept on the projects managed in the other two departments. More financial authority was delegated to the Coast Guard in the past year and this appears to have exacerbated the problem of getting

information back from them. There is no central information on project milestones and in fact no documentated indication that all projects are being managed using this proven technique. Properly operated, a project milestone system makes it much easier to report on and monitor the progress of projects.

Once again it must be noted that good central co-ordination is a secondary consideration to good project management for this type of program. Without good project management, nothing will be accomplished. However, without effective central co-ordination of the program, the good results at the individual project level will not have their full beneficial impacts in terms of achieving program objectives. To be effective in this respect, central co-ordination must be informed. In specific terms of this program, unless they are kept informed, the central co-ordination unit cannot ensure that appropriate actions are being taken to achieve supplementary and long-term program objectives.

Further, unless they are kept informed, central co-ordination cannot take effective corrective action in those few cases where project management is faltering or where, despite good project management, essential results are not being achieved. Elsewhere in this report we have indicated that special efforts will be needed to solve critical problems of coping with emergency and rescue situations in the Arctic because projects to date have not been successfull in finding solutions to some severe problems. While central co-ordination has been to some extent aware of this, this is because they have kept themselves informed from a multiplicity of sources. It would have been impossible to draw any such conclusion from the information normally passed on to them by those responsible for the projects.

To take an example of problems at the individual project level, the 1983 Evaluation reported a project (#2055) to develop high intensity marine lights. This project was considered to be very important by Canarctic, the operator of the MV Arctic, as an aid to detecting ice hazards in Arctic darkness. Although at one point the project was supposed to have been already started, it was in fact dropped by the responsibility centre, TDC, (Transport Development Centre) with a verbal explanation that there were problems with the manufacturers. No formal report was submitted of the reasons why it was dropped. When the interview team visited the manufacturer to discuss another project, this project was also discussed. There seems to have been some confusion and disagreement. The manufacturer was not aware why the project was dropped and yet the technology appears to have promise. A more informed and active central co-ordination would have

been able to follow-up, help resolve problems and, even if the particular technology was not in fact appropriate, ensure that all possible efforts were made to meet the needs of the third party, Canarctic.

For these kinds of reasons and others, it is essential that central coordination have and use a well structured and up-to-date information system. It is therefore recommended that:

(1) the Energy and R&D section, which acts as the central co-ordinating unit for the program, have a simple milestone base project reporting system designed and installed for the Arctic Marine Transportation R&D Program, taking due caution to ensure that the paperwork burden on project managers is not more than is essential for the effective management of the program;* and

(2) consideration be given to withdrawing delegated financial and management authority from units that consistently fail to provide, on a timely basis, the information necessary to keep the central co-ordination unit informed about the progress and results of projects.

7.2 Technology Transfer

In the 1983 Evaluation it was observed that the major mechanism for technology transfer in the program was the fact that the research and development work has been contracted out to private firms. While this appeared adequate for projects involving the development of specific products and services, concern was expressed that this would not be sufficient to ensure that the private sector was adequately informed of general advances in knowledge, particularily in the areas of ship design and operations. It was therefore recommended that consideration be given to appointing a full-time technical liaison officer for the program.

These concerns were reinforced by the comments made in this respect by the firms visited across the country and the Industry Review Panel. A common complaint of the firms visited was that they did not know what work had been planned

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* Since the work for this review was completed, a project was initiated that should meet the needs of the central coordination unit for up-to-date information using monthly data which already exists at the responsibility centres.

or was in process or completed, and they had not been informed of project results. The Industry Review Panel observed that it appeared to them that the results were being kept secret.

To help overcome these kinds of problems, program management has arranged for some seminars to report results. While welcoming this advance, the Industry Review Panel did not think that this was sufficient. They suggested that, at least for any continuation of the program, sufficient staff and financial resources be allocated to produce a regular bulletin to the marine industry that would include summaries of planned work, projects in process and project results. The Industry Review Panel felt that ongoing efforts to communicate with the Canadian marine community were essential if Canadian industry is to gain full benefit from the program.

It should be noted that this recommendation reinforces and amplifies the recommendation made in the 1983 Evaluation. It specifies one way in which a technical officer should carry out his/her function. The technical officer might also take over the responsibilities for overall liaison with industry, for arranging seminars and for handling specific industrial inquiries.

The Panel further recommended that the basic policy on information should be one of full disclosure of results to interested Canadian parties. Where this is not possible or advisable immediately after the completion of the work, a date should be set when full disclosure will be made.

Data management and disclosure policies for the program are now under review and a report is expected shortly.

7.3 Co-ordination With Other Research Efforts

The Industry Review Panel was also concerned that efforts under the program not duplicate efforts that are being (or should be) made elsewhere. As far as the international scene is concerned, it supported the efforts made under the program to obtain international co-operation and exchange in order to transfer foreign technology to Canada. It emphasized the need to continue these efforts. Inside Canada, it emphasized the need for co-ordination between government programs and for co-ordination between the government and industry.

Co-ordination between government programs is needed both to ensure that efforts are not duplicated and to ensure that significant problems do not fall between areas of responsibility, and therefore do not get addressed. Floating

exploration and production platforms and stationary storage vessels were discussed as examples of potential problems. As stationary work and storage structures these would tend to come under the regulatory and research purview of COGLA (Canadian Oil and Gas Lands Administration) whereas as moving (and movable) marine vessels they would tend to come under the purview of Transport Canada. As a result of this, efforts could be duplicated. Alternatively because of conflict or uncertainty as to who was responsible, necessary work could be stalled or overlooked.

The major means of co-ordination within the government has been the interdepartmental committee that was established to effect it. This committee reviews planned projects to ensure there is no duplication and helps to establish priorities. While this appears to have been an effective mechanism overall, additional efforts may be necessary to negotiate a settlement where program efforts overlap or problems seem to fall between areas of jurisdiction.

The Marine Advisory Board of industry representatives was designed as the formal mechanism of communication with industry and of co-ordination of marine transportation research efforts between the government and private industry. For a number of reasons this did not function as well as a co-ordinating mechanism as was hoped, but recent changes should make this more effective. The function has been expanded to include four regional boards with particular kinds of responsibilities (including one board situated in the prairies that is specifically responsible for Arctic research and development work).

The Industry Review Panel considered this function and recommended a significant management role for the Arctic Marine Advisory Board. It recommended that this Board review all subject areas of study and specific projects before implementation to ensure that there is no duplication of work that is being done by industry, and to ensure that the program does not undertake work that should be carried out by industry on its own. It also recommended that the Board regularily monitor, review and assess projects and results.

The use of the Arctic Marine Advisory Board to approve, monitor and review projects would probably be neither appropriate nor feasible. The detailed understanding they would require in order to be able to do so effectively (to say nothing of the amount of time) would be far more than what could be reasonably expected from what is essentially a voluntary service. It would be far more productive to have them review and approve proposed areas of study to ensure that these were not areas that were being, or should be,

studied by industry by and for itself. It would also be useful to have them monitor progress in these study areas and advice when and where in their opinion additional efforts are required.

7.4 Future Objectives

After reviewing past results and benefits from the program and considering future alternatives, the Industry Review Panel recommended that the program, with certain modifications, be continued for another five years after March, 1986 with an interim comprehensive review by an external group in 1989.

The first proposed modification, already noted, is to officially expand the focus of the program to include research and development work to resolve marine transportation problems under Arctic-type conditions in Canada's east coast waters.

A second proposed modification of the program affects the relative weight of the various components of the program objectives. The Panel noted that the urgency of developing year-round marine transportation in the Arctic had been lessened by events. The energy crisis has been mitigated and postponed and the Arctic has not yet proven to be as rich as expected in oil and gas. Thus they concluded that for the immediate future what were supplementary rather than central objectives of the program - to assist Canadian technological development and to improve (seasonal) Arctic marine transportation services - should become the central objectives of the program.

The evaluators do not agree precisely with either of these proposed modifications.

As to the first, if the geographical restriction (north of 60°) is to be removed from the program, a new geographical restriction should not be imposed instead. The case has been made for the efficiency of attaking similar (i.e. ice-related) problems under one program rather than restricting this to a geographical area. Further there are potential benefits to Canada and Canadian marine firms (including the operators) of finding solutions to ice-related problems in all Canadian waters. Therefore if the program is to be expanded in scope, it should be expanded to tackle problems of providing marine transportation under Arctic-type conditions wherever they are found in Canadian waters.

As to the second, there are significant difficulties with this recommendation especially with the recommendation that

assisting Canadian technological development become a prime objective of the program. The Arctic Marine Transportation Research and Development Program was designed and initiated to assist government in meeting its obligations to provide for the safe navigation of Arctic waters and to provide effective and efficient infrastructure services. Finding solutions to the identified problems in doing this is essential if industry is to operate safely, effectively and efficiently in the Arctic waters. Further, as the panel themselves have stressed, industry itself should bear the primary responsibility for organizing, resourcing and managing research designed specifically to solve industry's problems. Moreover the program has been successful to date in assisting industry technologically because it has been clearly focussed on technologically challenging problems of common concern to industry and government. It would therefore be both inappropriate and a strategic error to make industrial development a direct and primary objective of the program. Nonetheless, the intent to maximize industrial spin-offs and benefits from this work must be clearly highlighted in the objectives of the program and not lost sight of in the allocation of program resources.

The step by step improvement of Arctic navigation has always been a basic objective of the program as a necessary means of reaching the ultimate goal of safe and efficient year-round navigation in these waters. The advantage of having this ultimate goal as the central mission of the program is that it provides a high degree of technological challenge and thus assists technological innovation. The disadvantages are that the program might wrongly be judged to be unsuccessful until this goal is attained and that work on significant practical improvements of seasonal navigation might be overlooked in the pursuit of this ideal goal. Thus the objectives need to high-light the logical link between the shorter term and the longer term goal.

Taking these factors into account, the suggested statement of the strategic objective would be:

To: provide for the safe and efficient shipment of resources on a year-round basis on Canada's Arctic waters and (as appropriate) other Canadian waters with Arctic-type conditions;

By: planning, managing and providing financial support for, mission-oriented applied research which will assist in (a) the development of appropriate regulations, (b) the provision of basic knowledge necessary for safe navigation in these waters, and (c) the improvement in effectiveness and efficiency of government marine

transportation infrastructure services in the Arctic and under Arctic-type conditions;

And in so doing: to provide Canadian industry and marine operators with access to technologies which will assist them to compete effectively in the provision of vessels, equipment and services for marine transportation in the Arctic and under Arctic-type conditions.

7.5 Future Evaluations

The Industry Review Panel recommended that the program, as modified, be approved and funded for another five years with a comprehensive evaluation after three years (i.e. in 1989-90) by an independent external group.

The structure of this evaluation could usefully combine features of the 1983 Evaluation and the 1984-85 Review. It would therefore involve collection of data from the departments involved and from firms in the marine industry in order to:

(a) review the program structure and the nature of projects undertaken to ensure that these are necessary and sufficient to achieve objectives;

(b) document additional results of the program with respect to regulations, government services and industrial benefits; and

(c) ensure that continuation of the program beyond 1990-91 would be justified in terms of continuing benefits and any revised priorities.

The information should then be passed through two stages of review. A panel of internal and external experts who have been involved in the program should first review the information and the program to ensure sufficiency of work to achieve objectives and to ensure completeness of the listed results. Subsequently an independent panel drawn from the marine community should review the information and the program to ensure necessity of the work undertaken relative to objectives, to assess the adequacy of results and to consider the future of the program in relation to future benefits and existing priorities. Based upon the comments of the Industry Review Panel members from the 1984-85 Review, it would assist this panel in their deliberations if in addition to the types of information given to 1984-85 panel, they were given somewhat detailed descriptive presentations on the conduct and outcomes of a representative sample of projects.

It was felt that this qualitative data would help the panel members, who will not have been directly involved in the program, to get a feel for the nature of the program and work they will be assessing.

7.6 Conclusion

While the results of the program to date demonstrate that it is essentially well directed and managed, there is, nonetheless, some room for improvements.

The central co-ordination of the program is less effective than it could be because it is not provided with the information necessary for it to be fully effective. It was therefore recommended; (a) that an appropriate milestone-based project and program information system be designed and implemented and (b) that provision of up-to-date information to keep central co-ordination informed, be enforced, if necessary, by removal of delegated management and financial authority.

There have been problems in the transfer of knowledge and technology to Canada's marine industry. It was therefore recommended that resources be allocated to establish a technical information and liaison function for the program. This could include responsibility for arranging for the publication of a regular bulletin to the Canadian marine industry of program plans, progress and results as well as responsibilities for general industrial liaison, arranging technical seminars and responding to industrial enquiries.

Program efforts at international and national co-ordination and co-operation were supported. It was noted that some special efforts may be needed for intra-government co-ordination to avoid potential duplications of efforts in parallel areas of responsibility and to ensure at the same time that significant problems do not fall between perceived responsibilities. It was also suggested that the Arctic Marine Advisory Board should take on a significant management role in the program to ensure proper co-ordination of government and private sector research and development work.

Finally, while it is recommended that the program approval and funding be continued for another five years it is also recommended that the scope and objectives of the program be modified in three ways. First, the scope of the program should be expanded to include the study of problems posed by Arctic-type conditions (i.e. ice and weather) in all Canadian waters. Second, the importance of improving seasonal Arctic marine transportation should be stressed as a means to the long-term goal of year-round navigation in the Arctic.

Third, while the program must remain focused on government responsibilities for regulations and marine services, the objectives must highlight the intention of assisting the technological development of Canadian industry through addressing these technologically challenging problems.

It is also recommended that the next comprehensive review of the program be conducted in 1989. This evaluation should incorporate features of the 1983 Evaluation and the 1984-85 Review.

APPENDIX A

WRITTEN SUBMISSIONS FROM INDUSTRIAL FIRMS

1. THE CANADIAN SHIPBUILDING AND SHIP REPAIRING ASSOCIATION
2. ARCTEC CANADA LIMITED
3. PETER S. HATFIELD LTD.
4. PRATT AND WHITNEY CANADA
5. ROLLS-ROYCE INDUSTRIAL AND MARINE LIMITED
6. STELCO INC.
7. PORT WELLER DRY DOCKS
8. CANADIAN MARINE DRILLING LTD.

CANADIAN SHIPBUILDING AND SHIP REPAIRING ASSOCIATION
L'Association des Chantiers Maritimes Canadiens

Suite 801 - 100 Sparks Street — Ottawa, Canada K1P 5N7
Telephone (613) 232-7127 — Telex 053-4848

FILE: ARCTIC 3107

September 25, 1984

8113-2

Mr. Wayne Ellwood
Chief
Marine Research & Development - Energy
Transport Canada
Tower A, 22nd Floor
Place de Ville
Ottawa, Ontario
K1A 0N7

CMRD

Received - Reçu
OCT 1 1984
CMRD

Re: R&D in Marine Transportation

Dear Mr. Ellwood:

The Bureau of Management Consultants who are doing a study on the subject for Transport Canada have suggested that the CSSRA present their views on a number of questions. This letter constitutes the Association's response as well as the detailed views of several of our members. Our views were sought on the three questions set out below with our replies.

Question A

"What industrial capacity exists in Canada (or can economically be developed) to competitively meet market requirements for vessels, equipment and services for marine transportation (a) in the Arctic and (b) elsewhere for (i) national markets and (ii) international markets?"

Reply

A.1 The July 1984 edition of the CSSRA Directory of Services, Products, Facilities (copies given to consultants) sets out capacity of individual shipyards, repair firms and allied industries.

A.2 Steel capacity of shipyards is given at Annex A.

A.3 CSSRA yards can and have competitively (a most subjective term in today's world of surplus shipbuilding capacity and dumping) built:

A.3.1 Crude and product tankers up to 80,000 dwt.

. . . 2 . .

A.3.2 Semi-submersibles and jack-up drill rigs for domestic and export markets.

A.3.3 Offshore supply vessels and seismic vessels.

A.3.4 Icebreakers for government and private sector at the leading edge of technology including the world's most powerful commercial icebreakers.

A.3.5 Bulkers, self-unloaders, tugs, fishing vessels and ferries for domestic and export markets.

A.4 From the above it can be seen that for domestic use the Canadian industry has the capacity to meet virtually all foreseeable shipbuilding and offshore requirements with the exception of very large crude carriers (VLCC's) that are likely to be required to transport oil from the High Arctic. Expansion of existing facilities (both Davie Shipbuilding and Saint John Shipbuilding have plans ready) or establishment of a new green field shipyard would be needed for very large ships.

A.5 As indicated in A.4, the Canadian industry does not have the capacity to build VLCC's which might be required for the international markets. It is in this area that is located the bulk of world surplus capacity and consequently where prices are most depressed. We do not think it would be in Canadian interest to enter the international markets for the sale of standard and VLCC ships at the present time.

Question B

"What types of research and development work should be encouraged and supported to maximize the probability that these capabilities would remain, or become, competitive for market requirements (a) for the Arctic and (b) for other areas, (i) nationally and (ii) internationally?"

Reply

B.1 In response to my letter dated August 21, 1984 (copy at Annex B) to CSSRA members, the following member companies have responded to me (others have replied direct to the consultants). Copies of their replies are enclosed at the Annexes shown. Additional replies will be forwarded as they arrive.

B.1.1 Arctec Canada Limited - Annex B.1

B.1.2 Peter S. Hatfield Ltd. - Annex B.2

B.1.3 John T. Hepburn, Limited - Annex B.3 (yellow booklet)

B.1.4 Pratt & Whitney Canada - Annex B.4

B.1.5 Rolls-Royce Industrial & Marine Limited - Annex B.5

B.1.6 Stelco Inc. - Annex B.6

B.1.7 Port Weller Dry Docks - Annex B.7

. . . 3 . .

B.2 It will be seen that the responses to Annex B recommend that the highest priority be given to requirements that are peculiar to Canadian needs and priorities. This may seem to be a self-evident approach but an examination of Canadian R&D expenditures over recent decades will indicate that we have often taken the exotic rather than the practical approach. Nuclear power, heavy water, urban rail transportation and corporate jet development are not priority Canadian requirements and yet this is where enormous sums, indeed the majority, of R&D money has gone. The results have been mostly disappointing and have not contributed to Canadian social or economic needs to a reasonable degree. On the other hand, we have most often been successful both domestically and in export markets when following our recommended approach. (e.g. Versatile harvesters, Bombardier's snowmobiles, De Havilland's bush aircraft, telecommunications, Pratt & Whitney Canada's PT6 engine. Less well known are exports from other CSSRA members including equipment from Litton System Canada, Canadian Marconi, John T. Hepburn, Lo-Rez Vibration Control, Spar Aerospace Ltd., Stephens-Adamson, Thomson-Gordon Limited and Wagner Engineering Ltd. All of these based on developments for the Canadian market.)

Question C

"How should this research be encouraged, supported and conducted?"

Reply

C.1 Company replies to this question are in Annex B.1 to B.7.

C.2 R&D by the private sector should continue to be encouraged by tax incentives. Government support programs should be easy to understand and administered efficiently. Unconscionable delays in getting Yes/No replies to proposals have disillusioned several of my members, especially the smaller companies, as to usefulness of these programs. The bureaucratic hurdles and obstacles are frustrating.

C.3 We believe the Marine Advisory Board should be the principal private sector source of advice and review of the Marine R&D program.

Sincerely yours

Henry M. Walsh
President

Encl.

ANNEX A

CSSRA SHIPBUILDING YARDS
ANNUAL STEEL HANDLING CAPACITY

	Max. Tons of Steel/Years	Employment (in recent years)
1) SMALL		
Purvis Navcon Shipyard Ltd.	1,500	100 - 200
Allied Shipbuilders Ltd.	3,500	200 - 300
B.C. Marine Shipbuilders and West Coast Manly	5,400	300 - 500
Bel-Aire Shipyard Limited	2,500	75 - 200
Marystown Shipyard Limited	4,000	500 - 600
Breton Industrial & Marine Ltd.	1,500	75 - 200
Georgetown Shipyard Inc.	2,500	100 - 250
Northern Arc Shipbuilders Ltd.	1,000	50 - 100
Pictou Industries Limited	5,000	200 - 400
Verreault Navigation Inc.	1,000	50 - 100
Subtotal	27,900	1,650 - 2,850
2) LAKE		
Collingwood Shipyards	15,000	800 - 1,200
Port Arthur Shipbuilding	10,000	200 - 500
Port Weller Dry Docks	15,000	600 - 1,000
Subtotal	40,000	1,600 - 2,700
3) LARGE		
Burrard Yarrows Corporation (Apr '83)	20,000	1,200 - 2,200
Halifax Industries Limited	10,000	500 - 1,200
Davie Shipbuilding Limited	35,000*	2,000 - 2,500
Marine Industrie Limitée	25,000	2,200 - 2,600
Saint John Shipbuilding Ltd.	50,000	1,500 - 2,000
Vancouver Shipyards Co. Ltd.	10,000	250 - 850
Versatile Vickers Inc.	15,000	500 - 800
Subtotal	165,000	8,150 - 12,150
TOTAL	232,900	11,400 - 17,700

* Maximum Dimension for Davie Shipbuilding Limited is 300 m x 60 m.

September 1984

ANNEX B

CANADIAN SHIPBUILDING AND SHIP REPAIRING ASSOCIATION
L'Association des Chantiers Maritimes Canadiens

Suite 801 - 100 Sparks Street — Ottawa, Canada K1P 5B7
Telephone (613) 232-7127 — Telex 053-4848

August 21, 1984

To: Technical Section and Allied Industries Members

Re: R & D in Marine Transportation

The Transport Canada Marine Administration has commissioned a study on the subject, the results of which are likely to have a powerful influence on what Marine R & D projects are undertaken by Government in the next five years and the level of funding. The consultants who are doing the study are now collecting data and holding preliminary meetings with various groups including government program and regulatory personnel, shipping and shipbuilding firms and industrial associations.

The consultants met with me today. The questions for the CSSRA are as follows:

A. What industrial capacity exists in Canada (or can economically be developed) to competitively meet market requirements for vessels, equipment and services for marine transportation (a) in the Arctic and (b) elsewhere for (i) national markets and (ii) international markets?

B. What types of research and development work should be encouraged and supported to maximize the probability that these capabilities would remain, or become, competitive for market requirements (a) for the Arctic and (b) for other areas, (i) nationally and (ii) internationally?

C. How should this research be encouraged, supported and conducted?

I have provided oral answers to these quesions. However, it would be much better to get the advice of all of the Technical Section and the Allied Industries members on items B and C. With your replies, I will then consolidate a CSSRA response which should reflect the broader R & D requirements of the industry.

Our reply is required by the consultants by September 30, 1984. I would therefore ask for your replies to reach me no later than September 21, 1984.

Sincerely yours,

Henry M. Walsh
President

ANNEX B.1

ARCTEC CANADA LIMITED

311 LEGGETT DRIVE. KANATA. ONTARIO K2K 1Z8 TELEPHONE (613) 592-2830 TELEX 053-4733

September 12, 1984

Mr. H. Walsh,
President,
Canadian Shipping & Ship Repairing Association,
Suite 801 - 100 Sparks Street,
Ottawa, Ontario
K1P 5B7

Dear Henry,

Here are some thoughts for the consultant on Marine Transportation R&D. Obviously we have a fairly biased and strong opinion!

I too am talking directly to the consultant and will perhaps address more specific details.

Generally I believe we have a good program in Canada and about the right funding level. I'd like to see improvements in cooridination, prioritising and - most importantly - dissemination and use of results!

I'd like to sea a copy of your reply in due course.

Sincerely yours,

I.F. Glen,
President.

IFG/dr
encl.

ALSO AT: #16 - 6325 11th Street S E Calgary Alberta T2H 2L6 Telephone (403) 253-4883 Telex 0382-1972

MARINE R&D

General

The role of Government funded R&D in Marine Transportation should be to:

a) Promote the technological data needed to perform Government tasks (regulations, operations, etc.) efficiently and effectively.

b) Provide information needed to assist an industry (that has little or no discretionary revenues for R&D) to maintain a competitive position in the world in the provision of Marine Transportation systems.

c) To develop an indigenous R&D capability, particularly relevent to the unique Canadian environment, (the Arctic), which can be exported to other maritime nations.

While Government R&D should be specific to its own needs, it must also have a mandate to fund - either directly - or through incentives to the industry - on-going general research and development of relevance to the industry as a whole.

Types of R&D

A) Arctic

We must continue to ensure that Canada has the expertise and technology to ensure safe Arctic shipping through a regulatory base and through the provision of vital information to the Canadian Industry.

This is necessary to ensure that we retain sovereignty control over our Northern Waters, and to combat the likelihood that other nations will have greater knowledge of and capability in, the Canadian Arctic.

This R&D should encompass:

Environmental Definition
Design Criteria and Regulations
Operating data and procedures
Materials and fabrication,etc..

In addition to assuring that Canada remains in control of its Arctic waters, this technology may be considered an export to those other nations with similar interests. Such exportation is justifiable on the grounds that returns gained may be used to further enhance our capability.

The single most important technology to be developed through controlled co-operative ventures is that of engineering and fabrication of large Arctic vessels and structures.

B) East Coast

Our requirements here are less unique. Nevertheless, there are opportunities for initiatives and unique solutions to the problem of Transportation in iceberg covered waters, and heavy seas. In addition energy saving programs for the vast owner-operator fishing fleet should be in place.

C) Elsewhere

Canada's significant coastal/inland trade should be encouraged as alternative transportation systems and unique solutions to the problems seen in Canada sought.

Support of R&D

R&D is encouraged in Canada through favourable tax legislation. This form of encouragement along with directly contracted R&D is adequate. Awareness of tax advantages for R&D in the shipbuilding industry must be raised.

The present system of contracting out through TDC and various other divisions of Transport require some refining as they are frequently competing for funds and often little information flows among sponsors. Essentially, TDC should continue to contract out long-term, non-project work, while more project specific research should be funnelled through a control Transport Canada R&D group. NRC (IMD) must also assume a role in sponsoring transportation R&D. Methods to encourage industry (users) to fund needed R&D must be sought.

A joint industry/Government body should set priorities for the R&D.

Improved methods of disseminating R&D results to the users in the industry must be found and positive moves to ensure that results are followed-up and applied put in place. Techniques include:

- Seminars, publications, a bibliograph of reports with summaries, assignment of R&D contractors to shipyards, etc..

The least effective way of disseminating info is to circulate large R&D reports!

Finally, R&D should be conducted by qualified contractors and industry. While some long term research may be performed in Universities, they are often unaware of real industry requirements.

ANNEX B.2

PETER S. HATFIELD LTD.
NAVAL ARCHITECTS AND MARINE CONSULTANTS

PETER S. HATFIELD, B. Sc., P. ENG.
GORDON A. PASSMORE, C. ENG.
GRAHAM A. ROBBIE

1230 — 355 BURRARD STREET
VANCOUVER, B.C. V6C 2G8
(604) 683-4441

September 18, 1984

Canadian Shipbuilding & Ship Repairing Assn.
Suite 801, 100 Sparks Street
Ottawa, Ont.
K1P 5B7

Attention: Mr. Henry M. Walsh, President

Reference: R & D in Marine Transportation
Your letter of August 21, 1984

Dear Henry:

We offer the following as subjects for R & D for Canadian marine, construction and allied industries services and equipment suppliers:

Item B

a) Arctic

Materials; materials handling, joining and forming; material supply; structural use of materials; productivity methods and records; personnel training and training facilities; quality assurance; transportation and operations economics; future trends/requirements, estimating, scheduling, project management, market research.

Specialized industry vessels peculiar to Canadian Arctic operations.

b) Other Areas

As above without cold environment emphasis.

Specialized industry vessels peculiar to Canadian Coastal operations, such as log barges, log carrying vessels; tugboats; fishing vessels; self propelled barges and rail car ferries.

Technology transfer and market surveys for Canadian type of specialized marine equipment for international markets.

Item C

R & D in marine transportation in Canada should be administered and directed under long term planning worked out in conjunction with all levels of government and industry.

Funding assistance should be through DRIE programs such as IRDP but streamlined for administration and broader based for eligible projects. Tax incentive and research grants should be instigated. All public funded R & D in Canada should be undertaken in Canada at Canadian facilities and with Canadian equipment, unless positive proof exists that facilities or equipment are lacking.

Canadian marine transportation/industry has many innovative developments to its credit due to existing operating conditions and environment. This should be expanded upon and the proper long term emphasis, incentives and assistance will contribute to continued development.

Yours very truly,

PETER S. HATFIELD LTD.

P.S. Hatfield

P.S. Hatfield
PH/lm

PRATT & WHITNEY CANADA

ANNEX B.4

5 September 1984

Mr. H. M. Walsh, President
Canadian Shipbuilding and Ship Repairing Association
Suite 801 - 100 Sparks Street
Ottawa, Ontario
K1P 5B7

Reference: CSSRA Memo to Members 21 August 1984

Subject: R&D in Marine Transportation

Dear Mr. Walsh:

Your above referenced memorandum indicates that there is a useful opportunity to suggest again a Canadian initiative in developing a modern high-efficiency gas turbine combined cycle powerplant for LNG tankers, Arctic tankers, icebreaking, bulk carriers, etc.

Canadian industry is already involved in the manufacture of suitable gas turbines, namely, the Rolls-Royce Spey and RB 211, and there are several Canadian manufacturers of steam turbines, boilers, etc. What is required is the engineering and demonstration of a complete combined cycle system based on these existing Canadian units. Pratt & Whitney Canada has a propulsion system design and supply capability and is intimately familiar with gas turbine engines and combined cycle requirements. We believe that Canadian industry is well situated to pursue a viable high-efficiency propulsion system that would meet the needs of future high powered Arctic and other vessels.

You may also be interested in the attached copy of a report of a "Working Group on Propulsion Systems for Large Ice-Breaking Vessels" held on April 15, 1983 in Ottawa. This report focussed quite strongly on the combined cycle propulsion concept.

Pratt & Whitney Canada Inc.
Industrial & Marine Division

I hope this material is of use to you and eventually to Transport Canada, and the Canadian marine community.

Sincerely,

R. M. Sachs,
Marketing Director

fn
Encl.

CANADA/JAPAN COOPERATION IN ARCTIC MARINE TRANSPORTATION R&D

WORKSHOPS ON INDUSTRY INVOLVEMENT

APRIL 15, 1983 - OTTAWA

REPORT OF WORKING GROUP ON

PROPULSION SYSTEMS FOR LARGE

ICE-BREAKING VESSELS

Members:

Chairman	Peter Eggleton	- EDTDC/Mtl
	Bill Urwin	- Fleet Systems
	Walter Ross	- DRIE
	Bruce Tedford	- Rolls Royce
	Germain Milo	- External Affairs
	Bob Sachs	- Pratt & Whitney
	Jean B. Santrosi	- German & Milne Inc.
	Malcolm Comming	- Esso Resources

1. The group concluded that the objective (relative to its purview) of the feasibility activity is:

   "What could be done with the Japanese in Propulsion System R&D that could help realize in Canada a large propulsion system for ice-breaking vessels".

2. The group agreed there is a need for a national strategy to be defined in Canada involving the Arctic and marine transportation.

3. The group concurred that there are unknowns and problems with all propulsion system elements sized for Arctic applications. The principal sub-component groupings are:

   3.1 Prime Movers

   3.2 Transmissions

   3.3 Shafting

   3.4 Thrusters.

   These groupings are further divided in the "attachment".

4. The group determined which component areas had already established industrial Canadian capability: e.g.

   4.1 Prime Mover - gas and steam turbine.

   4.2 Transmissions - electric drives instrumentation and equipment.

5. The group identified a list of questions to be forwarded to Japanese side e.g.

   5.1 What is the Japanese state-of-the-art in each component area? This is expected to be demonstrated by supplying professional papers, design studies, research reports, prototype demonstrations and operational experience.

   5.2 What can be done to reduce sizing in all components? What tests have been done to determine loads imposed on large propellers and shafts?

5.3 Have Japanese done any research into modification of existing design standards e.g. classification formulae?

5.4 What data have Japanese collected and analyzed on their ice-breakers?

5.5 Regarding prime movers, what investigations have been conducted into - a) cooling water intake ice accumulation and
b) diesel engine operation and performance in extremely cold temperatures.

6. It was concluded that a good area of collaboration may be found in the application of Combined Cycle Gas Turbine/Steam Turbine (COGAS) propulsion for LNG carriers. This would build upon existing Canadian gas and steam turbine industrial capability plus electrical drive capability. It was proposed that the DRIE Office of Industrial Benefits study this opportunity for direct application into one of the proposed DOME/LNG carriers (or any of LNG carriers being built in Japanese yards for such services to Australia, Indonesia, Brunei, and other LNG producers). This proposal would be considered a first "demonstration of Canadian technology" and any premium over conventional systems for this operational prototype could be supported from existing R&D funds. The reason for selecting one of the DOME LNG carriers is that it would inherently be a shared Canadian/Japanese activity and would be a lower risk prelude to a higher risk Arctic class vessel installation.

7. For the initiating phase of COGAS activity, it was recommended that a preliminary design and economic feasibility study be commissioned in Canada. It was considered that a parallel examination be encouraged to be undertaken by the Japanese, with periodic exchanges with Canadian counterparts.

Peter L. Eggleton

PLE/ltb
TDC, Montreal

ATTACHMENT

PROPULSION SYSTEM COMPONENTS FOR LARGE ICE-BREAKING GAS TURBINES

Prime Movers

- Diesel
- Gas Turbine
- Steam Turbine

Transmission Devices

- Electric Transmission including superconducting homopolar electric machine
- Gear Drives
- Hydrostatic Transmissions

Shafting Elements

- Shafting
- Shaft Seals
- Bearings
- Couplings

Thrusters

- Monoblock Propellers
- Controllable Pitch Reversing Propellers
- Nozzles
- Hull/Propeller Interaction
- Ice Interaction.

$
CSSRA OTT

ROYCAR MTL A

NR 01333 840919 1842

HM WALSH - CSSRA OTTAWA

RBD IF MARINE TRANSORTATION

REF CSSRA MEMO OF AUG 2184 TO ALLIED INDUSTRIES MEMBERS. OUR RESPONSES TO YOUR QUESTIONS ARE AS FOLLOWS:

A. THE INDUSTRIAL CAPACITY ALREADY EXISTS IN CANADA TO SUPPLY HIGH EFFICIENCY COMBINED CYCLE (GAS AND STEAM TURBINE) PROPULSION SYSTEMS FOR LNG CARRIERS, ARCTIC RESOURCE CARRIERS, POLAR ICEBREAKERS, ETC. FOR EXAMPLE, THE ROLLS ROYCE MARINE RB211 MADE BY RR CANADA COULD BE COMBINED WITH A WASTE HEAT BOILER BY FOSTER WHEELER AND A STEAM TURBINE BY WESTINGHOUSE CANADA TO FORM A HIGH POWER HIGH EFFICIENCY PROPULSION SYSTEM THAT WOULD HAVE A REASONABLY LARGE CANADIAN CONTENT. THE MAKET FOR SUCH A SYSTEM WOULD BE MOSTLY IN THE CANADIAN ARCTIC OR ANY DOMESTIC LNG PROJECTS

B. TO PROMOTE THE DEVELOPMENT OF SUCH A CANADIAN PROPULSION SYSTEM GOVERNMENT FINANCED RESEARCH SHOULD BE DIRECTED TOWARDS THE MANUFACTURE OF A DEMONSTRATION UNIT TO PROVE THE VIABILITY OF MARINE COMBINED CYCLES SYSTEMS. AT PRESENT THE MARINE COMMUNITY VIEWS THIS TYPE OF PROPULSION SYSTEM AS UNPROVEN AND UNTRIED

C. RESEARCH IN SUCH SYSTEMS IS ALREADY BEING PURSUED BY THE TRANSPORTATIN DEVELOPMENT CENTRE OF TRANSPORT CANADA. FURTHER ENCOURAGEMENT OF TDC IN THESE GOALS BY GOVERNMENT WOULD BE OF GREAT ASSISTANCE TOWARDS ACHEIVING THE GOAL IN PARAGRAPH B

REGARDS

BRUCE TEDFORD BBT149
ROYCAR MTL/RGM
$
CSSRA OTT

ROYCAR MTL A

ANNEX B.6

stelco

Stelco Inc.

General Office
Stelco Tower
Hamilton, Ontario
L8N 3T1
(416) 528-2511
P. O. Box 2030

September 20, 1984

Mr. Henry M. Walsh
President
Canadian Shipbuilding and
Ship Repairing Association
Suite 801, 100 Sparks Street
Ottawa, Ontario
K1P 5B7

Dear Mr. Walsh:

I am replying on Stelco's behalf to your August 21 letter concerning R&D in marine transportation. My reply reflects our long-term interest in supplying plate steels for marine transportation applications.

In response to question B, we believe that localized weld zone corrosion and low weld heat affected zone toughness are two of the major technical problems facing the steel supplier.

The severity of the weld zone corrosion problem is not clear although we are aware that it is of concern for ships operating in the Gulf of St. Lawrence and for structures in Arctic marine environments.

The weld fracture toughness concern stems largely from North Sea experience with both fixed and mobile offshore structures. We believe that it may be extremely difficult to meet the tentative fracture toughness requirements being suggested for structures in Hibernia and the Arctic offshore.

There is a need for welding procedure/consumable development to parallel any plate development to overcome these two problems.

A further concern of ours is that recent advances in plate production, such as controlled rolling, are not being fully utilized by the designer or the fabricator either because they are not familiar with these advances and the advantages to be gained from them, or because of outmoded restrictions in specifications or by classification societies. An example of this, which is now receiving some attention, is the requirement for a maximum yield strength to ultimate strength ratio.

With respect to question C, we believe that a key aspect is to clearly define the critical technical problems with the agreement of the designer, fabricator, steelmaker, classification society, regulatory body and owner. Canadian R&D resources are such that we can afford to work only on the real problems. Organizations such as CANMET and C-FER should be encouraged to provide a coordinating role to ensure that the important technical barriers are being identified.

I hope the above will be of some value. Please give me a call if you have any questions (416-528-2511, ext. 262).

Yours truly,
Stelco Inc.

J. E. Hood
Research Manager
Product Development

JEH:NL

ANNEX B.7

PORT WELLER DRY DOCKS
A DIVISION OF ULS INTERNATIONAL INC.
P.O. BOX 3011 — ST. CATHARINES, ONT. L2R 7C1 — TELEPHONE (416) 934-2581
CABLES PORTWELLERDOC
TELEX 061-5136

September 24, 1984.

Canadian Shipbuilding and Ship Repairing
Association
Suite 801
100 Sparks Street
Ottawa, Ontario
K1P 5B7

Attention: Mr. Henry M. Walsh,
President

Reference: R & D In Marine Transportation

Dear Henry:

On September 12, 1984 Mr. S. Mathews and Mr. J. Atack visited P.W.D.D. regarding the above topic and Mr. A. Elliott and myself had a very meaningful discussion with them.

With regard to paragraph (B) of your letter we indicated that R & D in energy conservation should be encouraged and that a specific project should be the re-engining of steam propulsion lakers with diesel engines resulting in fuel savings of at least 33 percent. There are sufficient of these vessels around that productivity could be increased 'ramatically if a standard conversion for all vessels could be developed and Canadian content could be increased if the engine required was to be finally assembled and tested here.

We also indicated that R & D should be encouraged in the greater use of aluminum in the superstructures of cargo vessels etc. and fast patrol vessels so that Canadian shipyards would have the latest equipment to fabricate aluminum & be competitive with other countries.

As far as item (C) of your letter obviously participants in the R & D program would have to make detailed proposals of projects and be encouraged to proceed by being given all, or some of, the necessary funding to do so.

We trust that the above can be added to other comments that you have received.

Yours very truly,

A. G. Urquhart.

A. G. Urquhart,
Director of
Marketing.

AGU:ml

R & D IN MARINE TRANSPORTATION

Prepared in response to
Canadian Shipbuilding and Ship Repairing Association
letter dated August 21, 1984

HEPBURN

JOHN T. HEPBURN, LIMITED
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17 September 1984

Canadian Shipbuilding & Ship Repairing Association
Suite 801, 100 Sparks Street
Ottawa, Ontario
K1P 5B7

Attention: Mr. Henry M. Walsh

Gentlemen: Re: R & D in Maritime Industries

Further to your letter of 21 August 1984 concerning the above, we wish to respond as follows:

QUESTION A Existing Industrial Capacity

John T. Hepburn, Limited designs and manufactures marine deck machinery, listed on the attached Appendix 'A' and used in offshore oil, fishing, naval and commercial maritime markets.

Specific examples of equipment supplied for use in the Arctic include:

(a) Anchor Winches (photo B2723C in Appendix "B") and fairleaders suplied to Gulf Canada Resources Inc. Conical Drilling Unit (photo B2783C).

(b) Mooring Winches (photo B2760C) and Fairleaders supplied for a work barge owned by Arctic Transportation Limited.

(c) Deck Cranes, Mooring Winches and Anchor Windlass for service on an icebreaker (photo B2172C).

In the international market we have supplied, for example:

(a) Combination Traction Winch/Windlasses (photo B2747C) together with storage winches used on an oil rig in the North Sea. This equipment is at the forefront of world technology as it permits the continuous hauling in/paying out of combination wire/chain mooring lines which are preferred for deep water mooring.

(b) Replenishment-at-sea Systems to the navies of France, Italy and Australia. Note this equipment has potential applications in ship/rig transfer of personnel or supplies in the offshore oil market.

(c) Anchor Windlasses for offshore oil platforms (photo B2756C).

We also enclose our Marine Equipment Installation List and Marine Products Brochure in Appendix "C" which gives additional information on our products and markets.

Engineers and builders of overhead cranes, mine hoists, hydraulic presses, machine tools, marine equipment and machinery for rolling mills, pulp and paper processing, mines and other custom machinery. Fabricators and erectors of steel structures. Gray and ductile iron founders. HEPBURN

All orders are accepted subject to delays occasioned by accidents, strikes (including those by our own employees), fires, loss or delay in transit or causes beyond our control.

With regard to industrial capacity, we wish to point out our capability with regard to Project Manufacturing, i.e. manufacturing equipment to designs supplied by others. Our large, modern and well-equipped welding, machine and assembly shops coupled with almost 80 years of manufacturing experience, permits us to handle large and complex projects. We have been quite successful in offering this Project Manufacturing to both domestic and international customers.

QUESTION C Research and Development

We have carried out and will continue to conduct research and development in our marine equipment product line. While we would welcome assistance in this area, we strongly believe that this is not the solution to optimum future development.

Virtually each item in our product line is designed and manufactured to suit the requirements of each individual application. Substantial costs may therefore be incurred for engineering on a specific project and these costs cannot be spread over a large unit volume base.

Our international competition, in certain areas, may already have designs. With large domestic market bases they have spread, or are capable of spreading, development costs over a larger unit volume and may have volume manufacturing efficiencies. In such instances we are, therefore, at a distinct competitive disadvantage regarding price and delivery.

In other areas we are, theoretically, not at a competitive disadvantage. Such areas include large, unique, or special purpose equipment where both ourselves and our competition must start from scratch and face similar development costs.

In practice, however, we are still at a disadvantage in the export market. Due to formal rules and regulations and even informal practices on the part of foreign shipyards, shipowners, consultants and governments:

(a) we may be prevented from getting on the bidders' list;
(b) our bid may be evaluated with an unfavourable technical, financial or commercial bias;
(c) our bid may not be evaluated;
(d) even if we are successful it may be on the basis of having the equipment manufactured locally (i.e. not in Canada).

..... 3

On one hand we are faced with these barriers and obstacles to doing business overseas, yet on the other hand our internatioal competition has virtually unrestricted access to what little there is left of the Canadian market.

With a minimal domestic market and obstacles to the export market, the returns from encouragement and support of R&D are therefore not optimized.

The first step should be the encouragement and support of actual construction and supply of equipment by the domestic shipbuilding and allied industries. This is practised in foreign markets and is particularly applicable when the end use of the rig or vessel is in the exploitation of a government controlled resource such as oil and gas.

Such a first step in itself would encourage R&D by providing a domestic market for which domestic industry would compete. In addition, and where required, it could also provide added incentive for the transfer of technology, from foreign sources who, given the present circumstances, would prefer to retain production for their own overseas facilities.

We trust the above will assist you in responding to the study in question.

Yours very truly,

JOHN T. HEPBURN, LIMITED

By: James F. Hepburn

James F. Hepburn
Vice-President

JFH/ms

CANADIAN MARINE DRILLING LTD.

BOX 200
CALGARY, ALBERTA, CANADA
T2P 2H8

(403) 231-3000

January 01, 1985

Supply and Services Canada
Bureau of Management Consulting
365 Laurier Avenue West
Ottawa, Ontario
K1A 0S5

Attention: Mr. J. Atack

Re: Artic Marine Transportation Research & Development Program

Dear Jim:

My apologies for the lateness of our response but attached is a document with our comments on Arctic Research & Development. Please do not hesitate to give me a call if clarification is required. Subject to your approval we would also like to consider submitting this to one of the Canadian Marine journals for publication.

REGARDS,
CANADIAN MARINE DRILLING LTD.

BENGT M JOHANSSON

1985-01-14

CANMAR'S COMMENTS ON ARCTIC MARINE TRANSPORTATION
RESEARCH & DEVELOPMENT PROGRAM

The research program has achieved a great deal in four years. The program, either by direct funding or at least by support of industry activity, has undertaken projects ranging from theoretical studies through model tests to full scale testing. The full scale tests were ambitious and expensive but like other pioneering ship tests from the "Greyhound" to the "Lucy Ashton", were in the end the most rewarding. There is now a great deal of information for vessels up to 200 megajoules of kinetic energy and shafts up to 17,000 SHP. Two hundred megajoules represents the "Kigoriak" at 15 knots and 80 megajoules represents the "M.V. Arctic" at 4 knots. Seventeen thousand SHP represents the "Kigoriak". The program can claim to have made major developments in the understanding of ice loading and ship structural safety.

There are, however, two basic deficiencies. Further development of the Canadian Arctic will involve contact with multi-year ice. None of the existing vessels are large enough or strong enough to operate in significant multi-year ice and as a result, little full scale data exists. The second is the aspect of size. We have data at 200 megajoules but the "M.V. Arctic" at 14 knots is 1000 megajoules. A Class 6 Panamax OBO would be 2000 megajoules while a Class 10, 200,000 ton tanker would be 12,000 megajoules. The problems are therefore how to deal with multi-year or glacial ice at the large ship, high energy input level. It is a problem of scaling.

The aspect of model testing and scaling is the most disappointing. Model testing in open water is done:

- to predict the ship's performance which is important for economics; and,
- to avoid expensive mistakes such as vibration.

It is cost effective and can achieve ± 10% accuracy for typically less than 1% of the ship's cost. The recent experience with the model of the R Class icebreaker illustrates the problem for ice testing. This model was run in 6 basins and the measured resistance of the same model varied by ±35%. With this model resistance variation, what chance is there to scale up the model by 20 times and have an accuracy better than ±35%. Clearly, a great deal of expertise is required in order to do useful predictions. To rely on full scale tests is both expensive (5% of ship's cost) and restrictive (you only get one hull form and you cannot modify it until building another ship). There is definitely, therefore, an incentive to achieve reliable ice model testing.

The problem with multi-year ice is potentially more simple. At present, there are no ships that can successfully operate in, and break, multi-year ice. Building the theoretical models which are required to describe the phenomena and allow designers to design is therefore very difficult. It is rather like asking Newton to describe gravity but not allowing him to observe any effects of gravity, such as apples falling. We must observe the phenomena before we can understand it.

The problems of scaling every aspect of a ship from today's data to large commercial vessels can be described by taking one example. The required strength of the shaft; we know from the work undertaken in the program that a nozzle 3.5/5 metres in diameter restricts the ice torque to typically twice that of hydrodynamic torque. What we do not know, except by theoretical extrapolation, is whether this same quantitative effect will be in operation with say, a 7-metre nozzle. We also do not know what quantitative effect that going for deeper submersion of a propeller will have. We think it will reduce ice loads; we do not have any proof. There are many unanswered questions such as this which have resulted in very conservative designs which are also very expensive.

But now the question is, how to move into the future. The following is a list, in order of effectiveness, of ways of structuring a research program for the end of the 60's and the early 90's.

1. Build and test a large strong ship, say 50,000 to 80,000 tons, with 35,000/70,000 SHP with Class 6/10. This would answer most of the questions including that of the model scaling. Increasingly, the economics of an OBO or tanker of this size, servicing Nanasivik, Polaris, Panarctic and the Beaufort Sea, look good.

2. Build a Class 8/10 icebreaker. One problem here is the difference in requirements. The CCG require a multi-role vessel which is expensive to build and to operate. Industry requires a simpler vessel. A potential solution is to build the simple vessel so that afterward its roles can be expanded by the later addition of further accommodation modules, laboratories, etc..

3. At the very least, continue to do selective tests on existing vessels, extending to testing aspects of safety and performance in operations and ice conditions for the particular operation of each vessel.

4. The existing work needs to be understood and interpreted, argued and debated. We must now translate about $15 million worth of Arctic marine transportation research into something useful and practical for regulatory bodies, designers and operators. They are the end users. It will require the best brains and a great deal of outgoing cooperation and communication, together with supporting projects.

5. Last but not least, making model testing bear fruit. Canada is now in possession of what appears to have the potential to become the best ice-testing facility in the world. It is being commissioned. It is very important that the facility realises its potential and utilizes the expertise already existing in current Canadian facilities. A solution might be to start by testing all the vessels for which good full scale data is available, typically the Canadian Coast Guard ships, Canarctic, Canmar and Beaudrill ships with the objective of finding a scaling method which retro-predicts the real full scale performance of all these vessels. Such a method would give real confidence for designers.

WE ALSO THOUGHT THAT IT MIGHT BE APPROPRIATE TO PUBLISH THIS RESPONSE IN ONE OF THE CANADIAN MARINE JOURNALS. WE LOOK FORWARD TO YOUR REPLY.

APPENDIX B

TACTICAL OBJECTIVES OF THE PROGRAM

(SPECIFICATION OF IDENTIFIED NEEDS FOR KNOWLEDGE, SYSTEMS AND PRODUCTS REQUIRED TO ACHIEVE THE STRATEGIC OBJECTIVE OF THE PROGRAM)

1. Regulatory: Design

To conduct field trials, laboratory tests and simulations and to investigate and analyse all alternative approaches in order to acquire the additional knowledge necessary to review and, where appropriate, delete, add to or amend, regulations under the Arctic Waters Pollution Prevention Act and other codes and guidelines which relate to the design of Arctic Class Vessels and other marine structures.

1.1 Hull Design Criteria: to determine optimum criteria for design of hull structures for safe and efficient navigation of Arctic waterways under specified climatological and ice conditions and to develop the instrumentation and mathematical models necessary for measuring and assessing ice impacts on ships hulls in order to carry out required research.

1.2 External and Structural Materials and Assembly: to determine the most appropriate types of steel and welding techniques, etc. for hulls and decks of Arctic Class Vessels to withstand impacts, vibrations and cold temperatures.

1.3 Ice Class Propellers and Housing: to determine optimum designs and criteria for propellers, drive and protective housing under Arctic conditions.

1.4 Ice Class Rudders and Steering Gears: to determine optimum designs for rudders and steering gears for manoeuvrability and safe operations in ice and low temperature conditions.

1.5 Ship Propulsion Systems: to determine power requirements by class and weight of vessels and optimal propulsion systems appropriate to operations in Arctic conditions of restricted and expensive fuel supplies and variable ice and weather conditions.

1.6 Protection of Exposed Machinery and Equipment: to determine requirements and appropriate methods for protection of machinery and equipment located in exposed positions on Arctic vessels.

1.7 Crew Accommodations: to determine appropriate specifications for crew accommodations for protection from environmental effects and prevention of stress in order to allow safe and efficient vessel operations under extreme climatic and darkness conditions.

1.8 Design of Arctic Class Fishing Vessels: to review standards for fishing vessels for Arctic waters in the light of increased knowledge of requirements for safe and efficient operations and the possibility of longer operating seasons.

1.9 Wharf Construction and Equipment: to determine optimal location and design criteria for Arctic wharves to minimize ice damage and facilitate docking and to determine appropriate criteria for design and location of wharf equipment for ice management and for loading and unloading under Arctic conditions.

1.10 Offshore Drilling Units: to develop and organize the knowledge and expertise necessary to determine criteria for structural standards for offshore drilling vessels and rigs operating under Arctic conditions.

2. Regulatory: Operations

To conduct field trials, laboratory tests and simulations and to investigate and analyse all alternative approaches in order to acquire the knowledge necessary to review and, where appropriate, delete, add to or amend regulations under the Arctic Waters Pollution Prevention Act and other codes and guidelines which relate to the operation and maintenance of vessels in Canada's Arctic waterways, including the specifications for safety and emergency equipment required by these vessels.

2.1 Operating Procedures: to determine requirements and appropriate guidelines

regarding load lines, speeds, watch cycles, navigation techniques, etc. for vessel operations under Arctic conditions.

2.2 Emergency and Rescue Procedures: to identify, develop and test appropriate emergency, survival and rescue procedures for Arctic conditions.

2.3 Safety and Emergency Equipment: to identify, develop and test lifesaving and survival equipment appropriate for Arctic climate and daylight conditions, including reviewing special problems for life boat operations and supplies and equipment necessary for crew survival.

2.4 Staffing and Training: to ascertain the effects of year round navigation in the inhospitable Arctic environment on present rules and practices governing officer certification, crew training and manning levels through studies on human reactions to year round Arctic activity and associated stress and workload levels.

2.5 Survey, Repair and Salvage: to determine appropriate standards and practices for the survey and repair of vessels operating under various conditions in the Arctic.

2.6 Operation of Arctic Class Fishing Vessels: to review operating guidelines and regulations for fishing vessels in Arctic waters in the light of increased knowledge of requirements for safe and efficient operation and the possibililty of longer operating seasons.

3. Regulatory: General

To collate, analyse and interpret data collected within the Arctic Marine Transportation Research and Development Program and to collect further data on social, economic and ecological impacts in order to identify and delineate regulatory implications for classification of areas and vessels, for restriction of navigational routes, and for design and operation of vessels and other marine structures.

3.1 Classification of Arctic Vessels and Areas: to acquire and organize knowledge of normal seasonal ice, sea state and weather conditions in the various areas of the Arctic and of the structural, design and operating implications for vessels navigating or stationary in these areas in the different seasons to determine appropriate relative classification of areas and vessels for regulatory purposes.

3.2 Social, Economic and Ecological Impacts: to identify the probable effects of increased and year round marine traffic in the Arctic on the ecology of the Arctic and socio-economic life of the resident citizens.

3.3 Stationary Vessels: to determine appropriate standards and guidelines for vessels to be used as storage depots for fuel and other commodities.

3.4 Operating Routes: to study the long term need for regulated and restricted navigational routes in Arctic waters.

3.5 Regulatory Overview: to collate, analyse and interpret all data collected in the program and elsewhere which is relevant to the problems of marine transportation in Canada's Arctic waterways, especially year round transportation, in order to identify and delineate implications for regulations, codes and guidelines and to review alternatives for deletion, addition and amendment.

4. Operation of Vessels

To increase the safety and efficiency of vessels operating in all seasons in Arctic waterways by acquiring increased knowledge of design and operational requirements and by developing required ship-based systems and equipment.

4.1 Ship Based Ice Hazard Detection Methods and Equipment: to develop systems and equipment for proximate and remote ice hazard detection through investigation of illumination systems, radar, sonar, use of satellite data, remote sea-ice thickness sensors, etc.

4.2 Communications Systems and Technologies: to identify and develop communications systems which will operate reliably and effectively under Arctic weather and electromagnetic disturbance conditions and to ensure year round coverage of all probable navigation routes.

4.3 Ship Monitoring and Warning Systems: to develop knowledge, systems and equipment for measuring environmental effects on ships in Arctic waterways and warning those in charge when conditions approach maximum tolerances.

4.4 Arctic Navigational Systems and Methods: to develop standard and proposed navigational techniques and systems to Arctic requirements.

4.5 Ship Ballasting: to determine optimum ballasting techniques and equipment to operate in sub-freezing conditions and minimize still water bending moments.

4.6 Refuelling: to assess alternative means of refuelling vessels in Arctic waters.

4.7 Crew Training: to identify special needs and means of crew training for operations under Arctic conditions including exploration and/or development of simulator training modes and equipment.

4.8 General Design and Operating Information: to review and synthesize the data collected on design and operations for regulatory purposes and other research data, in order to provide basic information on design and operation of vessels for more effective and efficient movement in ice filled waters.

5. Government Services

To make safe and efficient navigation of Canada's Arctic waterways feasible in all seasons by acquiring the necessary basic knowledge and developing the systems and products required to provide year-round government marine services effectively and efficiently.

5.1 Arctic Charting Equipment: to develop and test methods and equipment which would allow more rapid and economical charting of Arctic waterways to modern specifications.

5.2 Remote Ice Measurement: to develop and test equipment for remote sea ice type identification and thickness measurement.

5.3 Arctic Climatology: to collect, collate and analyse weather, sea state and ice formation data to increase understanding of interrelations and to improve weather, sea state and ice conditions forecasting capabilities.

5.4 Local Ice Movement and Distribution: to observe ice conditions, distribution and movement in Arctic bays and seas in order to identify local seasonal patterns and to assist strategic route planning.

5.5 Weather, Sea State and Ice Forecasting: to develop systems and computer models for forecasting Arctic weather, sea state and ice conditions.

5.6 Ice Management: to determine/develop optimum methods of ice control and clearance for Arctic harbour.

5.7 Ice Transiting and Icebreaking Techniques: to develop more economical and effective icebreaking and ice transiting techniques to cope with year round ice conditions and improve trafficability through ice.

5.8 Arctic Class Nav-Aids: to develop appropriate designs for conventional and radio aids to navigational systems such that the structures and equipment will withstand Arctic weather and ice conditions and will operate reliably for long periods of time where access for maintenance is costly, limited and seasonally very difficult.

5.9 Ship Movement Planning and Monitoring: to develop a system for ice hazard risk prediction, for selecting optimal routes and

for tracking ship movements for routine communications and emergency actions.

5.10 Oil Spill Detection, Containment and Clean-up: to acquire special knowledge of oil movement in ice-filled waters for tracking spills, to develop and test methods and equipment appropriate for containment and clean-up under Arctic conditions, and to determine procedures and processes for alternative locations and situations.

APPENDIX C

LISTING OF PROJECTS BY TACTICAL OBJECTIVES

(SHOWING PROJECT NUMBER, RESPONSIBILITY CENTRE, STATUS AS AT DECEMBER, 1984, PROJECT TITLE AND A BRIEF DESCRIPTION OF THE PROJECT)

IDENTIFIED NEED: 1.1 Hull Design Criteria: To determine optimum criteria for design of hull structures for safe and efficient navigation of Arctic waterways under specified climatological and ice conditions and to develop the instrumentation and mathematical models necessary for measuring and assessing ice impacts on ship hulls in order to carry out required research.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2003	TDC	Completed 82/83	Polar Sea: Hull Strength	To investigate induced structural vibrations on the hull of the Polar Sea during field trials in northern waters with installed special equipment.
2005 (&2112 &2145)	TDC	Continuing Co-operative Work with U.S.	Polar Sea & Polar Star: Ice Loads and Response Criteria	To measure and analyse ice loads and hull structural response of the Polar Sea and Polar Star during Arctic & Anarctic voyages using installed special equipment.
2008	CG-Northern	Completed 82/83	Dome MV Canmar Kigoriak	To obtain data on hull impact loads and hull girder response from field tests on Kigoriak (Shared with Dome).
2009	CG-Northern	To be completed 84/85	MV Arctic: Hull Structure Field Tests	To collect data on structural response to ramming multi-year ice during MV Arctic operations.
2009A	CG-Northern	Planned for 85/86	Hull Structure Field Tests - Other Ships	To collect data on structural responses to ramming multi-year ice from other ships (Dome, Gulf, etc.)
2010-1	CG-Northern	Completed 83/84	Polar 8 Icebreaker Deployment: Ship/Ice Interaction Study	To develop specifications for a data system to record ship performance data and interface with alarm system to warn when systems or components are reaching their design limits.

IDENTIFIED NEED: 1.1 Hull Design Criteria: (Continued)

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2010-2	CG-Northern	Completed 83/84	Polar 8 Icebreaker Deployment: Ship/Ice Interaction Study	To develop an initial empirical approach and construct a finite element model of the proposed Polar 8 Icebreaker, and to use the model to simulate responses and assess structural design implications.
2011	CG-Northern	Completed 81/82	MV Arctic: Hull Girder Stress Investigation	To investigate hull girder stress during ramming of heavy first year ice during field tests with MV Arctic.
2012	CG-Northern	Completed 82/83	MV Arctic: Vibratory response, design loads & criteria	To collect data on hull girder stress, vibratory frequencies, resulting stress levels and bow force impact at various speeds.
2013	CG-Northern	Planned for 85/86	Vibratory Response: Field Tests on Another Ship	To collect comparable information to 2012 on another vessel.
2014	TDC	To be completed 84/85	MV Arctic Data: Dedicated Analysis	To undertake detailed analyses of data obtained from the permanent instrumentation system on the MV Arctic
2015	CG-Northern	Completed 83/84	MV Arctic: Statistical Measuring System	To measure loads on the bow structure (shear force, longitudinal stress, etc.) during field tests with MV Arctic.
2017	TDC	To be completed 84/85	MV Arctic: Optimization of Bow Form	To conduct model testing of selected bow forms in simulated ice and open water, calm and wave conditions to determine optimum form for typical ice conditions without impairing open water performance.

IDENTIFIED NEED: 1.1 Hull Design Criteria: (Continued)

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2024	TDC	Completed 82/83	Development of a Semi-Empirical Ice Resistance Model	To develop a model for relating shape, size and other relevant hull characteristics together with ice properties to resistance to motion of a vessel in ice.
2025	TDC	Completed 82/83	Ship Structural Response Model	To develop an analytical model to calculate dynamic response of ship structure under specified bow loads and to identify bow forces causing the response (transfer of technology from Finland).
2046	TDC	Completed 82/83	Wave climate documentation study - Arctic and offshore	To develop a methodology for relating wind and wave climatology in Arctic and offshore maritime regions of Canada to structural design criteria for ships and other floating structures.
2049	CG-Northern	To be completed 84/85	Arctic Ships: Load Lines and Stability	To review current regulations on load lines and intact stability of Arctic Class vessels to determine if they are adequate or should be revised in the light of data collected in recent years.
2094	CG-Northern	Completed 84/85	Participation with CANMAR	To investigate the global response to ice of Canmar Kigoriak and Robert Lemeur through analytical modelling and field tests.

IDENTIFIED NEED: 1.1 Hull Design Criteria: (Continued)

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2102	CG-Northern (NRC)	Completed 82/83	Ice Failure Modes	To collect data on mechanical properties of ice and to develop ice failure criteria for input into ship/ice interaction models. (incl. propeller ice interactions).
2129	CG-Northern	Complete 83/84	Modelling of Broken Ice around Icebreakers	To develop a model of structure and flow of broken ice around icebreakers to determine effects on mid hull, propellers, rudders, nozzles etc.

IDENTIFIED NEED: 1.2 External and Structural Materials and Assembly: to determine the most appropriate types of steel and welding techniques for hulls & decks of Arctic Class Vessels to withstand impacts, vibrations and cold temperatures.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2018 & 2019	CG-Northern	Tests completed in 82/83 and repeated in 84/85	MV Arctic: Destructive and Non-Destructive Testing	To examine specific areas, structural members and connections in the hull of the MV Arctic for flaws in order to further understand the behaviour of "A" grade steel at low temperatures and to test samples of "D" and "E" grade steel to assess fatigue properties and low temperature ductility.
2031	CG-Northern	Completed 83/84	Structural Steel Standards	To evaluate the cold temperature performance of "D" and "E" grade steels and the degree of reduction of risk of failure by brittle fracture.
2038	CG-Northern	Completed 81/82	MV Arctic: Requirement and Tests for Structural Steels	To test a sample of the deck plate of the MV Arctic to examine fatigue life & cold temperature with toughness properties.
2039	TDC	Completed 82/83	MV Arctic: Heat Flow Measurements	To obtain temperature and heat flow readings to provide coefficients and validate the finite element model developed to assess heat flows and associated cold temperature stresses in ships in order to determine steel properties required.
2109	TDC CG-Northern	Completed 83/84	MV Arctic: Brittle Fracture	To evaluate steel grades used and to assess risk of brittle fracture in main hull girder and bilge keel before and after replacement of some of "A" grade steel with higher grade. (two independent tests).
2140	CG-Fleet Systems	To be completed 84/85	Welding Technology: Review and Development WRT Corrosion	To conduct welding corrosion tests for Arctic conditions on selected materials and weld types.

IDENTIFIED NEED: 1.3 Ice Class Propellers and Housing: to determine optimum designs and criteria for propellers, drive and protective housing under Arctic conditions

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2023	CG-Northern	Completed 82/83	MV Arctic: Monitoring Machinery Requirements	To identify and quantity effects of ship response to icebreaking on machinery components (such as U/D box, propeller shafts, machinery mounts) to determine if regulatory provisions are necessary.
2027	TDC	Ongoing work	Ice Class Propeller Development	A group of related projects to collect, model and test propeller design/ice interactions.
2028	TDC	Started 84/85	Propeller/Ice Interaction: Full Scale Tests	To conduct field tests and collect data on propeller/ice interactions to define regulatory requirements.
2029	TDC	Initial work 82/83 followed up 84/85 to 85/86	Propeller Protection in Ice	To examine and test means of preventing propeller/ice contact, to improve the reliability and safety of ships operating in heavy ice.
2040	TDC	To be completed 84/85	Externally Pressurized Stern Tube Bearing	(long term): to develop a stern tube bearing that will last the life of the vessel under Arctic conditions. (short term): to manufacture and test a 1 scale hydrostatic stern tube bearing.
2129	CG-Northern	Completed 83/84	Modelling of Broken Ice around Icebreakers	To develop a model of structure and flow of broken ice around icebreakers to determine effects on mid-hull, propellers, rudders, nozzles, etc.

IDENTIFIED NEED: 1.3 Ice Class Propellers and Housing: (Continued)

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2146	TDC	To be completed in 84/85	Nozzle Propellers Ice Force II	To measure magnitude and location of ice forces on the blade of a CP propeller working in a nozzle and resultant effects on hub mechanism, shaft, etc.

IDENTIFIED NEED: 1.4 Ice Class Rudders and Steering Gears: to determine optimum designs for rudders and steering gears for manoeuverability and safe operations in ice and low temperature conditions.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2004	TDC	Completed 82/83	Ice Loads on Rudders & Steering Gears: Polar Sea	To design and install requisite instrumentation system, to collect data on ice forces on steering systems during 1982 voyage of Polar Sea, to analyse data and to build a model of ice/rudder interactions.
2007	CG-Northern	Ongoing work	Rudder Stocks, Steering Gear and Manoeuvrability	To determine optimum designs for rudders and stearing gears for manoeuvrability in ice and low temperatures.
2129	CG-Northern	Completed 83/84	Modelling of Broken Ice around Icebreakers	To develop a model of structure and flow of broken ice around icebreakers to determine effects on mid hull, propellers, rudders, nozzles, etc.

IDENTIFIED NEED: 1.5 Ship Propulsion Systems: to determine power requirements by class and weight of vessels for operating in Arctic conditions and optimal propulsion systems for Arctic vessels appropriate for Arctic conditions of restricted and expensive fuel supplies and variable ice conditions.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2104	CG-Aids & Water-ways	Ongoing work	Study of Speed/Power Loss of Vessels in Ice Infested Waters	To conduct model tests to develop safe design/ operational criteria for propulsion systems for vessels operating in ice infested waters.

IDENTIFIED NEED: 1.6 Protection of Exposed Machinery and Equipment: to determine requirements and appropriate methods for protection of machinery and equipment located in exposed positions on Arctic vessels.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2052	CG-Ship Safety	Planned for 85/86	Exposed Equipment and Systems	To ascertain what additional standards, if any, are required for ship equipment and systems for protection in Arctic environmental conditions.

IDENTIFIED NEED: 1.7 Crew Accommodations: to determine appropriate specifications for crew accommodations for protection from environmental effects and prevention of stress in order to allow safe and efficient vessels operations under extreme climatic and darkness conditions.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2053	CG-Northern	Completed 84/85	Crew Accommodation	To study facilities for crew on existing vessels and extrapolate for scenarios assuming longer exposure to environment etc. to provide background information to develop standards for the protection of the physical and psychological health of crews.

IDENTIFIED NEED: 1.8 Design of Arctic Class Fishing Vessels: to review standards for the design and construction of fishing vessels for Arctic waters in the light of increased knowledge of requirements for safe and efficient operation and the possibility of longer operating seasons.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2047	CG-Northern	To be completed in 84/85	Fishing Vessels in the Arctic and Subarctic	To review research and development findings for implications for standards for the construction of fishing vessels to operate in Arctic and Sub-arctic waters.
2131	TDC	Completed in 84/85	Ice Loads on Fishing Vessels	To measure, record and analyse induced loads and hull structural response on a fishing vessel operating in ice.

IDENTIFIED NEED: 1.9 Wharf Construction and Equipment: to determine optimal location and design criteria for Arctic wharves to minimize ice damage and facilitate docking and to determine appropriate criteria for design and location of wharf equipment for ice management and for loading and unloading under Arctic conditions.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2073	TDC	To be completed 84/85	Construction Standards for Arctic Ports and Marine facilities	To review design standards and construction practices, evaluate the adequacy of current standards for Arctic conditions and consolidate the results into an engineering manual on the construction of marine facilities (ports, harbours and navigational aids).
2101	CG-Aids & Waterways	To be completed 85/86	Ice Crushing Strength Research	To build a portable device to measure ice crushing strength in the Arctic environment and to collect data to gain knowledge of ice effects and resulting requirements for strength and design of structures and equipment.

IDENTIFIED NEED: 1.10 Offshore Drilling Units: to develop and organize the knowledge and expertise necessary to determine criteria for structural standards for offshore drilling vessels and rigs operating under Arctic conditions.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2045	CG-Ship Safety	Started in 84/85	Offshore Drilling Unit Standards	To acquire and organize the knowledge and expertise necesary for the approval of offshore drilling vessels and systems in the Arctic & Sub-arctic.

IDENTIFIED NEED: 2.1 Operating Procedures: to determine requirements and appropriate guidelines regarding load lines, speeds, watch cycles, navigation techniques, etc. for vessel operations under Arctic conditions.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2042	CG-Ship Safety	Completed 83/84	Arctic Ship Navigation Procedures	To study the effect of continuous darkness, continuous vibration and sleep loss on safe performance of duties.
2049	CG-Northern	Completed 84/85	Arctic Ships: Load Lines & Stability	To review current regulations on load lines and intact stability of Arctic Class vessels to determine if they are adequate or should be revised in the light of data collected in recent years.
2064	TDC	Ongoing work	Marine Simulator: R & D Options	To conduct studies on the hardware and software needs for an Arctic marine simulator for training and/or research purposes.
2098	CG-Fleet Systems	To be completed 84/85	Guidelines & Instructions for Mates and Masters	To collate requisite knowledge and to develop a manual on ice navigation practices and procedures for masters and mates of vessels operating in Arctic waters.
2106	CG-Telecomm.	Ongoing work	Preproject Studies for a CG Shiphandling Simulator	To identify target objectives for a ship-handling simulator for ice-covered water conditions with potential uses for training, port & channel design, identifying ship performance requirements, accident investigation, etc.

IDENTIFIED NEED: 2.2 Emergency and Rescue Procedures: to identify, develop and test appropriate emergency, survival and rescue procedures for Arctic conditions.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION

IDENTIFIED NEED: 2.3 Safety and Emergency Equipment: to identify, develop and test lifesaving and survival equipment appropriate for Arctic climate and daylight conditions, including reviewing special problems for life boat operations and supplies and equipment necessary for crew survival.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2116	TDC	Completed 83/84	Arctic Survival Capsule	To establish requirements for Arctic marine survival systems, evaluate existing equipment and outline an R & D program to address identified problems.
2125	CG-Northern	Completed 83/84	Lifesaving Equipment for Arctic Ships	To apply existing knowledge to the establishment of standards for lifesaving equipment and procedures for Arctic Class vessels.
2071a	CG-Ship Safety	Completed 83/84	Study on Synthetic Cordage	To study suitability and durability of cordage used on lifeboats and inflatible liferafts especially for Arctic conditions.
2071b	CG-Ship Safety	Completed 83/84	Study on Lifespan of Inflatible Liferafts	To study the lifespan and durability of inflatible liferatts especially under Arctic conditions.
2071c	CG-Ship Safety	Completed 83/84	Study on Lifeboat Equipment	To study the equipment and supplies carried in lifeboats and liferafts in the light of requirements for Arctic conditions.
2096	CG-Ship Safety	Completed 83/84	Operation of Diesel Engines on Life Boat	To review and evaluate the performance of existing lifeboat engines to determine whether current technology is adequate for low temperature operations and to recommend such further research work as is indicated by identified requirements versus available technology.
2071d	CG-Ship Safety	Ongoing Work	Arctic Lifesaving, Survival & Rescue	To study regulations in light of research and experience, test out alternative modes and equipment and prepare revisions as warranted.

IDENTIFIED NEED: 2.4 Staffing and Training: to ascertain the effects of year round navigation in the inhospitable Arctic environment on present rules and practices governing officer certification, crew training and manning levels through studies on human reactions to year round Arctic activity and associated stress and workload levels.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2051	CG-Ship Safety	To be completed 85/86	Arctic Operations & Manning	To ascertain the effects of year round navigation on present rules and practices governing officers certification and manning levels through studies on human reactions to year round Arctic activity and associated stress and workload levels.

IDENTIFIED NEED: 2.5 Survey, Repair and Salvage: to determine appropriate standards for the survey and repair of vessels operating under various conditions in the Arctic.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2054	CG-Northern	On going work	Survey Methods and Salvage Techniques	To study current practices for survey, repair and salvage worldwide, identify deficiencies in these methods regarding Arctic operations and develop proposals for further action.

IDENTIFIED NEED: 2.6 Operation of Arctic Class Fishing Vessels: to review operating guidelines and regulations for fishing vessels in Arctic waters in the light of increased knowledge of requirements for safe and efficient operation and the possibility of longer operating seasons.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2047	CG-Northern	To be completed in 84/85	Fishing Vessels in the Arctic and Sub-arctic	To review research findings and operating experience for implications for standards for the operation of fishing vessels in Arctic and Sub-arctic waters.

IDENTIFIED NEED: 3.1 Classification of Arctic Vessels and Areas: to acquire and organize knowledge of normal seasonal ice and weather conditions in the various areas of the Arctic and the structural and design implications for vessels operating in these areas in the different seasons to determine appropriate relative classifications of areas and vessels for regulatory purposes.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2043	CG-Northern	To be completed 84/85	Group III Studies	To develop a probability model to measure the risk of ship/ice collision in the different areas of the Arctic at various times of year to determine criteria for regulations.
2111	CG-Northern	Completed 82/83	MV Columbialand: Trafficability	To obtain and analyse data on trafficability from the MV Columbialand to be used as input into Group III studies on risk prediction.
2	EC-AES	Ongoing work	Microwave Sensing of Ice	To develop and test methods and equipment for microwave sensing of multi-year and first-year ice configuration from satellites.

IDENTIFIED NEED: 3.2 Social, Economic and Ecological Impacts: to identify the probable effects of increased and year round marine traffic in the Arctic on the ecology of the Arctic and socio-economic life of the resident citizens.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION

IDENTIFIED NEED: 3.3 Stationary Vessels: to determine appropriate standards and guidelines for vessels to be used as storage depots for fuel and other commodities.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION

IDENTIFIED NEED: 3.4 Operating Routes: to study the long term need for regulated and restricted navigational routes in Arctic waters.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION

IDENTIFIED NEED: 3.5 Regulatory Overview: to collate, analyse and interpret all data collected in the program and elsewhere which is relevant to the problems of marine transportation in Canada's Arctic waterways, especially year round transportation, in order to identify and delineate implications for regulations, codes and guidelines and to review alternatives for deletion, addition and amendment.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2044	CG-Northern	To be carried out 84/85 & 85/86	Regulatory Overview	as above

IDENTIFIED NEED: 4.1 **Ship Based Ice Hazard Detection Methods and Equipment:** to develop systems and equipment for proximate and remote ice hazard detection through investigation of illumination systems, radar, sonar, use of satellite data, remote sea-ice thickness sensors, etc.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2021	Can-arctic	Ongoing work	MV Arctic: Improvement in Ice Navigation	To install and test lighting systems and other equipment (e.g. light enhancing glasses, use of colour filters) to aid ice identification and navigation in darkness.
2057	Can-arctic & TDC	Project completed 83/84	Ice Hazard Detection: Satellite and Airborne Imaging	To develop techniques and shipborne equipment for using satellite and airborne imaging to facilitate detection of hazardous ice for strategic and tactical routing.
2111	CG-Northern	Completed 82/83	MV Columbialand - Trafficability	To obtain base field data on the encounter, detection and avoidance of hazardous ice.

IDENTIFIED NEED: 4.2 Communication Systems and Technologies: to identify and develop communication systems which will operate reliably and effectively under Arctic weather and electromagnetic disturbance conditions and to ensure year round coverage of all probable navigation routes.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2067	CG-Telecomm	Completed 82/83	Engineering Design Study	To obtain geological and other basic data affecting special requirements for determining most effective system.
2066	CG-Telecomm	Completed 82/83	HF/MF Antenna Measurements - Arctic Installations	To study existing coverage and antenna installations at Resolute, Frobisher and Inuvik to upgrade facilities to state-of-the-art.
2065	CG-Telecomm	Completed 84/85	Communications Control Console	To develop a remote control communications system for ship-shore communications which will meet Arctic requirements.
2097	CG-Telecomm	To be completed 84/85	Northwest Passage Communications Experiment	To investigate the use of VHF/UHF technique and equipment for Arctic use through experiments in the Northwest Passage.

IDENTIFIED NEED: 4.3 Ship Monitoring and Warning Systems: to develop knowledge, systems and equipment for measuring environmental effects on ships in Arctic waterways and warning those in charge when conditions approach maximum tolerances.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2115	TDC	Completed 83/84	Radisson: NAWS-Hull Stress Warning System	To develop a hull stress warning system to detect and measure structural strains caused by ice impacts and to provide a continuous display to alert navigation officers to severe stresses caused by impacts and pressures through development & installation of equipment and field trials aboard the Radisson in the Arctic.
2147	CG-Aids & Waterways	To be completed in 84/85	Naws Repeater	To test improvement in effectiveness of NAWS-Hull Stress Warning System by adding a repeater with an easily read display format.
2139	TDC	Started 84/85	Ship Hull Instrumentation	

IDENTIFIED NEED: 4.4 Artic Navigational Methods and Systems: to develop standard and proposed navigational techniques and systems to Arctic requirements.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2060	CG-Telecomm	Planned for 85/86	Loran-C Engineering Study - Beaufort Sea	To collect data for planning and estimating costs of a project to make Loran-C position fixing for navigation available in Arctic waters.
2136	CG-Telecomm	Ongoing work started in 84/85	Radio Navigation Investigation	To investigate the applicability of alternative communication aids to navigation under Arctic conditions and environment.
2138	CG-Telecomm	To be completed 84/85	Semi-Automatic Teletype - Over - Radio	To evaluate the use of existing commercial equipment to provide semi-automatic TOR terminals for CG Radio Stations in the Arctic.
2148	TDC	To be completed 85/86	Arctic Marine Navigation Database Modelling	To collect data or movement and activity to bridge personnel during Arctic navigation and create simulation model.

IDENTIFIED NEED: 4.5 Ship Ballasting: to determine optimum ballasting techniques and equipment to operate in sub-freezing conditions and minimize still water bending moments.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2020	Can-arctic/ TDC	Completed 82/83	MV Arctic: Rearrange-ment of Ballast Water	To investigate the potential for reducing the still water bending moment of the MV Arctic by rearranging the ballast water in the deep ballast condition.

IDENTIFIED NEED: 4.6 Refuelling: to assess alternative means of refuelling vessels in Arctic waters.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2095	CG-Northern	Completed 83/84	Refuelling - Polar Icebreaker	To assess existing refuelling infrastructure in the Arctic and recommend modifications/ alternatives for storing fuel and refuelling the proposed polar icebreaker.

IDENTIFIED NEED: 4.7 Crew Training: to identify special needs and means for crew training for operations under Arctic conditions including exploration and/or development of simulator training models and equipment.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2064	TUC	Ongoing work	Marine Simulator: R & D Options	To conduct studies on the hardware and software needs for an Arctic marine simulator for training and/or research purposes.
2106	CG-Telecom	Ongoing work	Preproject Studies for a CG Shiphandling simulator	To identify target objectives for a ship-handling simulator for ice-covered water conditions with potential uses for training, port & channel design, identifying ship performance requirements, accident investigation, etc.

IDENTIFIED NEED: 4.8 General Design and Operating Information: to review and synthesize the data collected on design and operations for regulatory purposes and other research data, in order to provide basic information on design and operation of vessels for more effective and efficient movement in ice filled waters.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION

IDENTIFIED NEED: 5.1 Arctic Charting Equipment: to develop and test methods and equipment which would allow more rapid and economical charting of Arctic waterways to modern specifications

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
66310	CHS (Atlantic)	Completed 84/85	Clearance Sweeping	To develop method of portable equipment capable of use with non-dedicated vessels for rapid sweeping of channels and port areas to determine minimum clearance.
66309	CHS (Atlantic)	Unit manufactured & several field trials completed	Autonomous Remote-Controlled Submersible	To develop, manufacture and test a remote controlled submersible vessel capable of collecting soundings and other data under ice and all weather conditions.

IDENTIFIED NEED: 5.2 **Remote Ice Measurement:** to develop and test equipment for remote sea-ice type identification and thickness measurement.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2058	TDC	Completed 84/85	Sea Ice Thickness Sensing System	To develop and test portable and air borne sea ice thickness sensors.
2	EC-AES	Ongoing work	Microwave Sensing of Ice	To develop and test methods and equipment for microwave sensing of multi-year and first-year ice configuration from satellites.
3	EC-AES	Completed 84/85	Laser Profilometer	To develop and test prototype equipment using laser reflections to get 3D profiles of ice to assist in distinguishing ice types and conditions.

IDENTIFIED NEED: 5.3 Arctic Climatology: to collect, collate and analyse weather, sea state and ice formation data to increase understanding of inter-relations and to improve weather, sea state and ice conditions forecasting capabilities.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
67125	DFO/IOS	25% Complete	Arctic Sea Ice Studies	To install acoustic sensor stations and to collect, collate and analyse sea-ice data.
1	EC/AES	Ongoing work	Marine Forecast System	To collate and process relevant data and to adapt methodologies and systems developed for East Coast sea-ice, sea state and marine weather climatological and forecast methods and systems to the Arctic region and to develop climatological and forecast operating systems for the Arctic application.

IDENTIFIED NEED: 5.4 Local Ice Movement and Distribution: to observe ice conditions, distribution and movement in the Arctic bays and seas in order to identify local seasonal patterns and to assist strategic route planning.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2022	Can-arctic	Studies conducted in 82/83 (and in 84/85 under Energy Program)	MV Arctic: Ice Regime Studies	To collect information on local patterns in ice movement for the MV Arctic's northern route to determine if such data assists in strategic route planning and reduction of damage from multi-year ice.

IDENTIFIED NEED: 5.5 Ice/Weather Forecasting: to develop systems and computer models for forecasting Arctic ice and weather conditions.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
1	EC/AES	Ongoing work	Marine Forecast System	To collate and process relevant data and to adapt methologies and systems developed for East Coast sea-ice, sea state and marine weather climatological and forecast methods and systems to the Arctic region and to develop climatological and forecast operating systems for the Arctic application.

IDENTIFIED NEED: 5.6 Ice Management: to determine/develop optimum methods of ice control and clearance for Arctic harbours.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2072	TDC	Completed 82/83	Maintenance of Arctic Ports and Harbours	To review and evaluate existing and proposed methods of ice management in ports and harbours and prepare recommendations on techniques to be used in the Arctic.
2070	TDC	Terminated 84/85	Air Cushion Platform Icebreaking	To bring to an operational level and evaluate performance of the ACIB at Thunder Bay and to develop and test prototypes in the Arctic.

IDENTIFIED NEED: 5.7 Ice Transiting and Icebreaking Techniques: to develop more economical and effective icebreaking and ice transiting techniques to cope with year round ice conditions and improve trafficability through ice.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2017	TDC	To be completed 84/85	MV Arctic: Optimization of Bow Form	To conduct model testing of selected bow forms in simulated ice and open water, calm and wave conditions to determine optimum form for typical ice conditions without impairing open water performance.
2113	TDC	Completed 82/83	Ultrasonic Doppler Velocimeter	To develop an ultrasonic volocimeter for ice-breakers which will allow readings of precise speed during icebreaking operations in order to minimize costs and fuel usage.
2102	CG-Northern (NRC)	Completed 82/83	Ice Failure Modes	To collect data on mechanical properties of ice and to develop ice failure criteria for input into ship/ice interaction models. (incl. propeller ice interactions).

IDENTIFIED NEED: 5.8 Arctic Class Nav-Aids: to develop appropriate designs for conventional and radio aids to navigational systems such that the structures and equipment will withstand Arctic weather and ice conditions and will operate reliably for long periods of time where access for maintenance is costly, limited and seasonally very difficult.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2059	CG-Aids & Waterways	Ongoing work	Low Temperature Frequency Agile Racons	To determine ability of new Racon technology to enhance the usefulness of shipboard radar in Arctic operations.
2073	TDC	To be completed 84/85	Construction Standards for Arctic Ports and Marine Facilities	To review design standards and construction practices, evaluate the adequacy of current standards for Arctic conditions and consolidate the results into an engineering manual on the construction of marine facilities for the Arctic (ports, harbours & navigational aids).
2080	CG-Aids & Waterways	Ongoing work	Development of Arctic Power Supplies	To test out alternate methods of power supply, storage and economization including wind and solar energy with low temperature operable storage batteries and low temperature recyclable 365 day load timer.
2081	CG-Aids & Waterways	Ongoing testing work	Containerized Arctic Nav-Aid Unit	To design and test a Nav-Aid package with cycle-charge diesel generator and full heat recovery to operate unattended for a year.
2093	CG-Aids & Waterways	Ongoing work	Stirling Cycle Generator	To evaluate propane-fuelled Stirling engines as a reliable low-power generator for unattended Nav-Aid and telecom sites in the Arctic.

IDENTIFIED NEED: 5.8 Arctic Class Nav-Aids: Continued

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2101	CG-Aids & Water-ways	To be completed 85/86	Ice Crushing Strength Research	To build a portable device to measure ice crushing strength in the Arctic environment and to collect data to gain knowledge of ice effects and resulting requirements for strength and design of structures and equip-ment.
2134	CG-Aids & Water-ways	Improved Arctic design to be tested starting 84/85	Development of Arctic Wind Generator	To test out wind generator designed for remote Arctic use.
2135	CG-Aids & Water-ways	To be completed 84/85	Remote Maintenance Diagnostic Monitoring	To evaluate the feasibility of using pro-grammed instrumentation to monitor and report on remote unmanned facilities in the Arctic.

IDENTIFIED NEED: 5.9 **Ship Movement Planning & Monitoring:** to develop a system for ice hazard risk prediction, for selecting optimal routes and for tracking ship movements for routine communications and emergency actions.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2043	CG-Northern	To be completed 84/85	Group III Studies	To develop a probability model to measure the risk of ship/ice collision in the different areas of the Arctic at various times of the year to determine criteria for regulations.
2057	Can-arctic TDC	Project completed 83/84	Ice Hazard Detection: Satellite and Airborne Imaging	To develop techniques and shipborne equipment for using satellite and airborne imaging to facilitate detection of hazardous ice for strategic and tactical routing.
1	EC/AES	Ongoing work	Marine Forecast System	To collate and process relevant data and to adapt methodologies and systems developed for East Coast sea-ice, sea state and marine weather climatological and forecast methods and systems to the Arctic region and to develop climatological and forecast operating systems for the Arctic application.
2060	CG-Telecomm	Planned for 85/86	Loran-C Engineering Study - Beaufort Sea	To collect data for planning and estimating costs of a project to make Loran-C position fixing for navigation available in Arctic waters.

IDENTIFIED NEED: 5.10 Oil Spill Detection, Containment and Clean-up: to acquire special knowledge of oil movement in ice filled waters for tracking spills, to develop and test methods and equipment appropriate for containment and clean-up under Arctic conditions, and to determine procedures and processes for alternative locations and situations.

PROJECT NO.	RESP. CENTRE	STATUS	TITLE	DESCRIPTION
2082	CG-Emerg.	Completed 82/83	Boom Evaluation	To test, evaluate and standardize lightweight oil containment booms which can be readily deployed to remote Arctic sites.
4	EC-AES	Ongoing work	Oil Spill Studies & Contingency Planning	To develop oil spill trajectory prediction capability for Arctic, to develop and test methods & equipment for clean-up and to develop contingency plans for alternate scenarios.

APPENDIX D

PROJECTED EXPENDITURES 1981-86 BY TACTICAL OBJECTIVES

(NOTE: FOR PROJECTS INCLUDED IN THE EXPENDITURE TOTALS, SEE APPENDIX C; WHERE A PROJECT APPLIES TO MORE THAN ONE TACTICAL OBJECTIVE, PROJECT EXPENDITURES HAVE BEEN DIVIDED EQUALLY AMONG THESE OBJECTIVES)

TABLE A

ARCTIC MARINE TRANSPORT RESEARCH AND DEVELOPMENT PROGRAM: ACTUAL AND PROJECTED EXPENDITURES, 1981/82 TO 1985/86 BY CATEGORY OF TACTICAL OBJECTIVE.

	ACTUAL EXPENDITURES			PROJECTED EXPENDITURES		
	81/82 $K	82/83 $K	83/84 $K	84/85* $K	85/86 $K	1981-86 $K
1. REGULATORY: DESIGN	622.6	1,794.2	1,720.3	2,271.1	2,986.0	9,394.2
2. REGULATORY: OPERATIONS	9.5	44.4	426.5	492.2	615.0	1,587.6
3. REGULATORY: GENERAL	76.4	129.3	315.5	225.5	310.0	1,056.7
4. OPERATION OF VESSELS	9.5	373.8	858.6	733.2	366.2	2,341.3
5. GOVERNMENT SERVICES	1,000.5	2,727.1	2,382.3	2,583.4	2,323.9	11,017.2
INTERNATIONAL TECHNOLOGY EXCHANGE	Ø	8.5	43.0	96.4	Ø	147.9
PROJECT MANAGEMENT AND PROGRAM REVIEW	Ø	10.0	74.3	81.8	Ø	166.1
TOTAL	1,718.5	5,087.3	5,820.5	6,483.6	6,601.1	25,711.0

* 1984/85 PROJECTIONS ADJUSTED FOR OVERCOMMITMENTS.

TABLE B

ARCTIC MARINE TRANSPORT RESEARCH AND DEVELOPMENT PROGRAM: ACTUAL AND PROJECTED EXPENDITURES, 1981/82 TO 1985/86 ON "REGULATORY:DESIGN" PROJECTS BY TACTICAL OBJECTIVE

		ACTUAL EXPENDITURES			PROJECTED EXPENDITURES		
		81/82 $K	82/83 $K	83/84 $K	84/85* $K	85/86 $K	1981-86 $K
1.1	HULL DESIGN CRITERIA	481.8	1,203.9	1,332.9	1,259.5	1,609.0	5,887.1
1.2	EXTERNAL AND STRUCTURAL MATERIALS AND ASSEMBLY	55.0	121.4	36.0	60.1	Ø	272.5
1.3	ICE CLASS PROPELLERS AND HOUSING	85.8	402.1	142.2	361.6	726.0	1,717.7
1.4	ICE CLASS RUDDERS AND STEARING GEAR	Ø	52.1	59.7	374.7	450.0	936.5
1.5	SHIP PROPULSION SYSTEMS	Ø	Ø	17.0	56.6	60.0	133.6
1.6	PROTECTION OF EXPOSED MACHINERY & EQUIPMENT	Ø	Ø	Ø	Ø	20.0	20.0
1.7	CREW ACCOMMODATIONS	Ø	Ø	38.0	38.9	Ø	76.9
1.8	DESIGN OF ARCTIC CLASS FISHING VESSELS	Ø	Ø	45.0	15.2	Ø	60.2
1.9	WHARF CONSTRUCTION AND AND EQUIPMENT	Ø	14.7	49.5	45.1	5.0	114.3
1.10	OFFSHORE DRILLING UNITS	Ø	Ø	Ø	59.4	116.0	175.4
	TOTAL	622.6	1,794.2	1,720.3	2,271.1	2,986.0	9,394.2

* 1984/85 PROJECTIONS ADJUSTED FOR OVERCOMMITMENTS.

TABLE C

ARCTIC MARINE TRANSPORT RESEARCH AND DEVELOPMENT PROGRAM: ACTUAL AND PROJECTED EXPENDITURES, 1981/82 TO 1985/86 ON "REGULATORY:OPERATIONS" PROJECTS BY TACTICAL OBJECTIVE

	ACTUAL EXPENDITURES			PROJECTED EXPENDITURES		
	81/82	82/83	83/84	84/85*	85/86	1981-86
	$K	$K	$K	$K	$K	$K
2.1 OPERATING PROCEDURES	9.5	31.3	87.5	131.8	100.0	360.1
2.2 EMERGENCY AND RESCUE PROCEDURES	0	0	0	0	0	0
2.3 SAFETY AND EMERGENCY EQUIPMENT	0	13.1	217.0	251.0	355.0	836.1
2.4 STAFFING AND TRAINING	0	0	61.0	58.8	60.0	179.8
2.5 SURVEY, REPAIR AND SALVAGE	0	0	46.0	38.9	100.0	184.9
2.6 OPERATION OF ARCTIC CLASS FISHING VESSELS	0	0	15.0	11.7	0	26.7
TOTAL	9.5	44.4	426.5	492.2	615.0	1,587.6

* 1984/85 PROJECTIONS ADJUSTED FOR OVERCOMMITMENTS

TABLE D

ARCTIC MARINE TRANSPORT RESEARCH AND DEVELOPMENT PROGRAM: ACTUAL AND PROJECTED EXPENDITURES, 1981/82 TO 1985/86 ON "REGULATORY:GENERAL" PROJECTS BY TACTICAL OBJECTIVE

	ACTUAL EXPENDITURES			PROJECTED EXPENDITURES		
	81/82	82/83	83/84	84/85*	85/86	1981-86
	$K	$K	$K	$K	$K	$K
3.1 CLASSIFICATION OF ARCTIC VESSELS AND AREAS	76.4	129.3	315.5	154.8	210.0	886.0
3.2 SOCIAL, ECONOMIC AND ECOLOGICAL IMPACTS	0	0	0	0	0	0
3.3 STATIONARY VESSELS	0	0	0	0	0	0
3.4 OPERATING ROUTES	0	0	0	0	0	0
3.5 REGULATORY OVERVIEW	0	0	0	70.7	100.0	170.7
TOTAL	76.4	129.3	315.5	225.5	310.0	1,056.7

* 1984/85 PROJECTIONS ADJUSTED FOR OVERCOMMITMENTS

TABLE E

ARCTIC MARINE TRANSPORT RESEARCH AND DEVELOPMENT PROGRAM: ACTUAL AND PROJECTED EXPENDITURES, 1981/82 TO 1985/86 ON "OPERATION OF VESSELS" PROJECTS BY TACTICAL OBJECTIVE

	ACTUAL EXPENDITURES			PROJECTED EXPENDITURES		
	81/82	82/83	83/84	84/85*	85/86	1981-86
	$K	$K	$K	$K	$K	$K
4.1 SHIP BASED ICE HAZARD DETECTION METHODS AND EQUIPMENT	0	100.8	327.5	376.2	0	804.5
4.2 COMMUNICATIONS SYSTEMS AND TECHNOLOGIES	0	104.0	417.0	67.2	0	588.2
4.3 SHIP MONITORING AND WARNING SYSTEMS	0	19.8	59.1	57.7	80.0	216.6
4.4 ARCTIC NAVIGATIONAL METHODS AND SYSTEMS	0	0	0	155.1	186.2	341.3
4.5 SHIP BALLASTING	0	63.9	0	0	0	63.9
4.6 ARCTIC REFUELLING	0	54.0	20.0	0	0	74.0
4.7 CREW TRAINING	9.5	31.3	35.0	77.0	100.0	252.8
4.8 GENERAL DESIGN AND OPERATING INFORMATION	0	0	0	0	0	0
TOTAL	9.5	373.8	858.6	733.2	366.2	2,341.3

* 1984/85 PROJECTIONS ADJUSTED FOR OVERCOMMITMENTS

TABLE F

ARCTIC MARINE TRANSPORT RESEARCH AND DEVELOPMENT PROGRAM: ACTUAL AND PROJECTED EXPENDITURES, 1981 TO 1982 ON "GOVERNMENT SERVICES" PROJECTS BY TACTICAL OBJECTIVE

		ACTUAL EXPENDITURES			PROJECTED EXPENDITURES		
		81/82	82/83	83/84	84/85*	85/86	1981-86
		$K	$K	$K	$K	$K	$K
5.1	ARCTIC CHARTING EQUIPMENT	246.0	827.7	566.0	354.0	243.0	2,236.7
5.2	REMOTE ICE MEASUREMENT	76.4	144.6	359.5	207.1	210.0	997.6
5.3	ARCTIC CLIMATOLOGY	174.5	425.9	585.4	878.3	878.3	2,942.4
5.4	LOCAL ICE MOVEMENT	0	163.8	0	0	0	163.8
5.5	ICE/WEATHER FORECASTING	24.5	39.0	56.3	94.3	94.3	308.4
5.6	ICE MANAGEMENT	406.8	507.6	131.6	138.5	0	1,184.5
5.7	ICE TRANSITING AND ICEBREAKING TECHNIQUES	0	172.4	87.1	29.1	0	288.6
5.8	ARCTIC CLASS NAV-AIDS	24.6	175.0	268.8	543.3	448.3	1,460.0
5.9	SHIP MOVEMENT PLANNING & MONITORING	0	124.8	274.9	49.8	55.0	504.5
5.10	OIL SPILL DETECTION, CONTAINMENT & CLEAN-UP	47.7	146.3	52.7	289.0	395.0	930.7
	TOTAL	1,000.5	2,727.1	2,382.3	2,583.4	2,323.9	11,017.2

* 1984/85 PROJECTIONS ADJUSTED FOR OVERCOMMITMENTS